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ASTM BULLETIN, January, 1948. Published six times a year, January, March, May, August, October, and December, by the American Society for Testing Materials. Publication Office—20th and Northampton Sts., Easton, Pa. Editorial and advertising offices at the headquarters of the Society, 1916 Race St., Philadelphia 3, Pa. Subscription $2.00 a year in United States and possessions, $2.25 in Canada, $2.50 in foreign countries. Single Copies—50 cents. Number 150. Entered as second class matter April 8, 1940, at the post office at Easton, Pa., under the act of March 3, 1879.

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ASTM BULLETIN

Published by
AMERICAN SOCIETY for
TESTING MATERIALS

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JANUARY—1948

No. 150

The ATLAS FADE-OMETER AND WEATHER-OMETER

Provide a means of quickly determining the color fastness and weathering qualities of Plastic Products.

Permanence of color or degree of fading on exposure to sunlight is determined in the Fade-Ometer.

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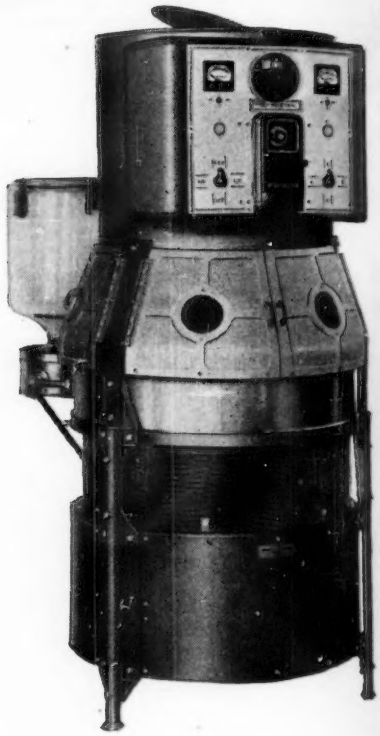
Years of actual exposure are reduced to a few days testing in your laboratory. Results are dependable and exact duplicate tests can be made at any time in the development of a stable plastic product.



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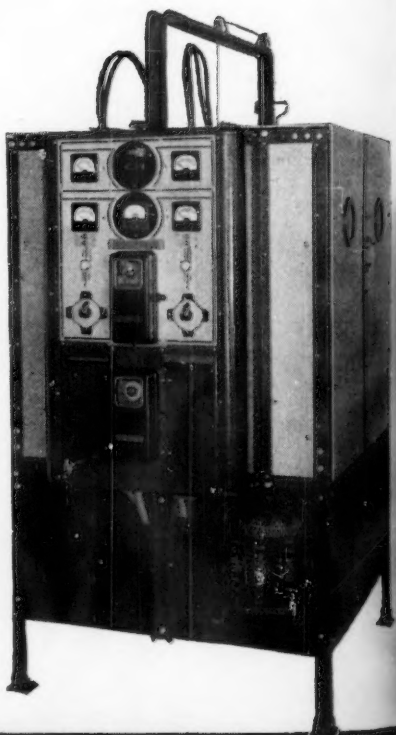
is the recognized standard testing machine for predetermining the fastness to light of any material or finish. Specimens are rotated around the Atlas enclosed violet arc—the closest approach to actual sunlight—in masked holders. Automatic temperature control to within ±3° F. and humidity regulated by a constant reservoir according to requirements of tests. Operation is completely automatic without attention from operator; can be left in continuous operation overnight.



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faithfully duplicates the combined weathering effects of sunlight, rain, heavy dew and thermal shock. Full automatic control of light and water periods is provided by the Atlas Cycle Timer unit which can be set to meet standard and special requirements of weathering tests. After setting exposure cycles on the control panel, the Weather-Ometer can be safely left in continuous operation without attention.

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ASTM BULLETIN

"Promotion of Knowledge of Materials of Engineering, and Standardization of Specifications and Methods of Testing"

TELEPHONE—Rittenhouse 6-5315

R. E. Hess, Editor
R. J. Painter, Associate Editor

CABLE ADDRESS—TESTING

Number 150 January 1948

Many Committees to Meet in Washington

About 150 Committee Sessions Scheduled

UPWARDS of 150 meetings of main A.S.T.M. technical committees and their subgroups and sections will be held during A.S.T.M. Committee Week in Washington, D. C., beginning March 1. As noted in the December BULLETIN, meetings of the respective committees are being allocated to the several cooperating Washington hotels, and in making hotel reservations members are asked to keep this situation definitely in mind—a hotel reservation form was sent to each A.S.T.M. member and committee member in December with detailed information on which committee would meet where.

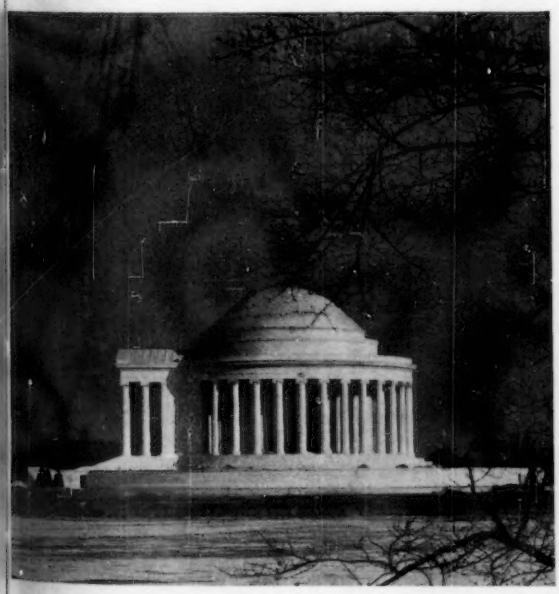
Detailed schedules of subcommittees will be, as usual, transmitted by the committee secretaries. No complete schedule will be sent from A.S.T.M. Headquarters but there will be available at the respective hotels in Washington full details on times and room assignments for the committees. Most of the meetings are being held at the Hotel Statler, but several groups will meet at the Mayflower, Shoreham, and Wardman Park.

There are no general technical sessions being held this year and consequently since such sessions comprise the main feature of the Spring Meeting, no cognizance is being taken of such a meeting.

The recommendations on standards and such matters which are agreed upon at the meetings and subsequently confirmed by letter ballot vote will be covered by reports to be presented at the Annual Meeting in Detroit during the week of June 21. However, as is customary, news accounts of the meetings will appear in the March ASTM BULLETIN.

A.S.T.M. Symposium on Organic Reagents for Metal Analysis

AN all-day symposium on "Organic Reagents for Metal Analysis" is being held on March 4 at the Shoreham Hotel in Washington, D. C., under the sponsorship of the American Society for Testing Materials' Committee E-3 on Chemical Analysis of Metals. While the symposium is being held primarily for the members of Committee E-3 and its subcommittees and certain invited guests, others interested in the subject are invited to attend and should make known their desire to do so to Dr. S. E. Q. Ashley, General Electric Co., Pittsfield, Mass., or Dr. J. W. Stillman, E. I. du Pont de Nemours and Co., Inc., Wilmington 98, Del. Dr. Ashley is chairman of Committee E-3's Division on General Analytical Methods and Dr. Stillman is secretary of the main technical Committee E-3.



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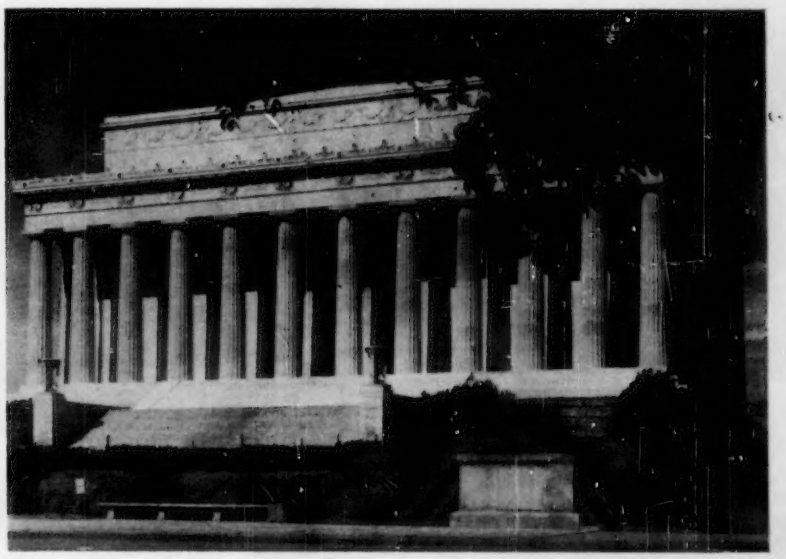

LINCOLN

Memorials to Two Great Americans

Notes on 1948 Annual Meeting

Numerous Features in Detroit, June 21–25; Lecture on Tracer Isotopes; Photographic Exhibits, with Photomicrography and Radiography

RECENT developments in connection with the 1948 Annual Meeting of the Society to be held in Detroit throughout the week of June 21 include a decision by the Board of Directors to invite Dr. Paul Aebersold, Chief, Isotopes Division, Atomic Energy Commission at Oak Ridge, to deliver the 1948 Edgar Marburg Lecture during the Annual Meeting. The general subject of Dr. Aebersold's address will be radioactive tracer isotopes, with special reference to their utilization in industry. Unless there is a change in the plans, this lecture will be held on the evening of Thursday, June 24, in the main auditorium of the Rackham Building, thus having available excellent facilities for a large audience. Further announcement will be made later. The Society is fortunate in securing as a speaker one who is in such close contact with this important subject.

Photographic Exhibit Committee:

Recently in Detroit the 1948 Photographic Committee was organized with J. L. McCloud of Ford Motor Co., general exhibits committee chairman, present, and also F. G. Weed, President, Rinshed-Mason Co., who is to serve as the Photographic Committee chairman. Serving with Mr. Weed are a number of members and others who are active in this field. A.S.T.M. Committees E-4 on Metallography and E-7 on Radiographic Testing are participating officially in the exhibit, and have designated representatives. The complete personnel of the Photographic Committee appears in the accompanying box.

The photographic theme this year will be "Materials, Testing, and Research," and full details and an entry blank will be sent to each member in the near future. In the Society are quite a number of men who do excellent camera work, and the exhibits of previous years have demonstrated their technique and also the interest in this subject. The work in photomicrography and radiography shown under the auspices of Committees E-4 and E-7, respectively, also has aroused much interest and focused attention on improved techniques and the excellent results which can be obtained.

1948 Photographic Committee

F. G. WEED, *Chairman*, President, Rinshed-Mason Co.
R. C. MCCLEARY, Chrysler Corp.
DON M. MCCUTCHEON, Ford Motor Co.
ANGELO R. SERRATONI, Chrysler Corp.
EUGENE VINCENT, Ethyl Corp.
H. R. WOLFE, General Motors Corp.

Representing Committee E-4 on Metallography:

C. J. TOBIN, General Motors Corp.
H. L. SHIPPEY, Bausch & Lomb Optical Co.

Representing Committee E-7 on Radiographic Testing:

DON M. MCCUTCHEON, Ford Motor Co.
E. W. PAGE, General Electric X-ray Corp.
H. E. SEEMANN, Eastman Kodak Co.
KENT R. VAN HORN, Aluminum Company of America

Apparatus Exhibit:

Many of the leading manufacturers and distributors of testing equipment, laboratory supplies, and materials used in testing and re-

search will participate in the 1948 Exhibit of Testing Apparatus and Related Equipment to be held at The Book-Cadillac throughout the five days of the Annual Meeting. This exhibit is an excellent opportunity for instrument manufacturers to contact a large group of men specializing in this field. The exhibit also points up the importance of the field of instrumentation in materials testing and research.

Technical Program:

A very comprehensive technical program is in the course of development, some details of which were announced in the December BULLETIN. A number of symposiums are planned and there will be a large number of papers and reports presented. There will be further information in the March BULLETIN and a complete Provisional Program will appear in the May issue. Work is already under way on editing papers, many of which together with the reports will be preprinted.

New Specifications for Facing Brick

THE Society by action of its Administrative Committee on Standards on November 24, 1947, approved the new Tentative Specification for Facing Brick (Solid Masonry Unit Made from Clay or Shale) (C 216 – 47 T). This specification, developed in Committee C-15 on Manufactured Masonry Units, was definitely needed in the industry since the requirements of facing brick are more stringent than for common or back-up brick. Considerable discussion took place in the committee and substantial agreement was finally reached. Three types of brick in each of two grades are covered. The grades designated SW and MW are for use, respectively, where a high and uniform degree of resistance to frost action and disintegration by weathering is desired, and where a moderate degree of resistance is permissible. The three types are as follows:

Type FBX—Brick for general use in exposed exterior and interior masonry walls and partitions and for use where a high degree of mechanical perfection, narrow color range, and minimum permissible variation in size are desired.

Type FBS.—Brick suitable for general use in exposed exterior and interior masonry walls and partitions where wide color ranges are desired and where a greater variation in size is permitted or desired than is specified for Type FBX.

Type FBA.—Brick manufactured and selected to produce characteristic architectural effects resulting from nonuniformity in size, color, and texture of the individual units.

The specification gives detailed physical requirements and covers numerous other matters of quality and testing. This specification is published in Part II, 1947 Supplement to the 1946 Book of A.S.T.M. Standards.

More Publications Issued

THE output of A.S.T.M. publications, both compilations of standards and symposiums and special technical books, continues apace. Notes on some books recently issued or scheduled for distribution very soon, appear here.

Compilations of Standards:

Three compilations of standards are practically completed, including those in the fields of paint, varnish and lacquer; cement; and the third, refractories.

The compilation sponsored by Committee D-1 on Paint, Varnish, Lacquer, and Related Products is considerably larger than the former edition published in February, 1946. Comprising almost 600 pages, it includes about 170 specifications, tests, definitions, etc. The standards are grouped under such headings as the following:

Pigments
Drying Oils, Paint Driers, and Thinners
Shellac, Varnish and Varnish Materials
Rosin, Dipentene, Pine Oil, and Tall Oil
Lacquer and Lacquer Materials
Traffic Paint
Paint Tests, Putty
Paint Weathering Tests

Copies of this widely used book can be procured by members at the special price of $3.25, the list price being $4.35.

The Compilation of Standards on Cement is sponsored by Committee C-1. A number of changes have been made in the specifications and tests. Members can procure this approximately 200-page book at the special price of $1.50; list price, $2.

Some of the compilations of standards include much helpful information in addition to the specifications and tests, and this is very definitely the case with the Manual on Refractory Materials sponsored by A.S.T.M. Committee C-8. This committee has developed a number of surveys covering the service conditions of refractories in a number of important applications, and these special reports are given in full in this latest book. Since there has been no edition since June, 1943, the new one will be of distinct service. There are about 40 specifications and tests included in this book which will aggregate about 260 pages. The members' price is $1.85, the list $2.50, in heavy paper cover; for cloth, an additional charge of 65 cents per copy is made.

Special Technical Publications:

The Symposium on Paint and Paint Materials, Special Technical Publication No. 75, has been completed. It has the several papers presented at the 1947 Spring Meeting, with an interesting introduction by C. H. Rose, Chairman of the Symposium Committee. He points out that there has been a marked increase in the interest within the industry in the methods of evaluating paints and paint materials and that the many new products being offered the paint industry must be evaluated carefully and with reasonable promptness. Hence Commit-

Of the publications described in the accompanying article four are not listed on the special Members' Order Blank transmitted in December and consequently could not have been ordered through the blank. They are the compilations of Standards on Cement and on Paints; the Petroleum-Automotive Papers; and the Engine Test Manual.

tee D-1 sponsored this symposium to focus attention on testing methods and to make available the latest thoughts and practices. The first group of four papers describes some of the current testing methods used for testing industrial, automotive, container, and marine finishes. The three papers in the next group describe some new developments in testing methods for evaluating paint materials. The last group of papers discusses the application of statistical analysis to test data and shows how paint testing may be facilitated by statistical methods. This book of 120 pages, heavy paper cover, is available to members at $1.50, the list price being $2. Cloth prices are 65 cents additional in each instance.

Petroleum Products and the Automobile:

Two extensive technical papers and an interesting introduction comprise the booklet covering the relation of petroleum products to the automotive industry, which was the general subject covered at the Detroit District meeting in October. W. M. Holaday, Director, Socony-Vacuum Laboratories, New York, prepared the extensive paper dealing with "The Efficient Production and Utilization of Motor Gasoline," and C. M. Larson, Chief Consulting Engineer, Sinclair Refining Co., New York, discussed "Petroleum Lubricating Oils as Related to Automotive Equipment." H. C. Mougey, Chairman of the Program Committee, introduces the papers and cites the significance of the general problem. Copies of this 52-page booklet can be procured by members at 75 cents per copy, the list price being $1.

Petroleum Chart:

Another chart is being added to the series of Viscosity-Temperature Charts described in A.S.T.M. Standard D 341. This is a low-temperature kinematic viscosity conversion chart of the 26 by 20-in. size. It supplements the other four charts which have been issued for a number of years covering the usual Saybolt and kinematic viscosity conversions. Like the other charts, the new one—termed Chart E—is published on tough, thin paper which can be blueprinted. Copies are available at 25 cents each; pad of 25 for $2, and the charge for 5 pads is $7.50.

Entrained Air in Concrete:

The nine technical papers and introduction to this symposium, held during the 1947 Annual Meeting, cover the various methods that have been developed and used to measure the air entrained in concrete by the use of air-entraining cements. The quantity of entrained air is subject to variation from a number of influences and it is highly important that accurate methods be available. This symposium covers the rolling and pressure method, the Indiana method, pycnometer method, the Ohio Method, and others. There is one paper giving an analysis of methods, based on the percentage of air in 45 batches of concrete. Following the general discussion there is a paper on the effect of sampling errors. Copies of this 96-page publication, a reprint from the *Proceedings*, are available to members at $1.30 per copy, the list price being $1.75.

A.S.T.M. Manual of Engine Tests for Fuels Being Published; Charts and Tables Available

A NEW publication that promises to be of widespread interest and utility for all those concerned with the evaluation of automotive, aviation, and Diesel engine fuels is nearing completion. This book entitled "A.S.T.M. Manual of Engine Test Methods for Rating Fuels" is issued under the sponsorship of A.S.T.M. Committee D-2 on Petroleum Products and Lubricants and gives in their latest approved form the five standard methods which are widely used. Not only are the methods given, but there is a great deal of supplementary information relating to the apparatus used, its operation, etc.

This is the first time that all of the extensive information and data necessary have been compiled under one cover. Those responsible for the preparation of the book have worked intensively and put in many long hours to have it as up to date and as useful as possible.

The tests for knock characteristics cover the following: Motor Fuels by the Motor Method (D 357) and the Research Method (D 908); Aviation Fuels by the Aviation Method (D 614) and the Supercharge Method (D 909). The fifth is the Test for Ignition Quality of Diesel Fuels by the Cetane Method (D 613).

The Manual includes a short statement on the significance of fuel ratings obtained by these standard A.S.T.M. methods. The extensive supplementary material covers the following: Apparatus, Reference Materials and Blending Accessories, Operation, Maintenance, Installation and Assembly, and Building and Utility.

Charts and Tables:

In addition to the Manual itself which will aggregate upward of 300 pages the Society is also issuing as a convenience a number of charts and tables which are required for recording the results, or which are a decided convenience if available on separate sheets. Facsimiles of numerous tables appear in the Manual, for example: Tables of Micrometer Settings; Octane Number Conversions for Fuel Blends; etc. These tables are being issued separately from the book in size 8½ by 11 in., and those interested can procure a list of the tables by writing to A.S.T.M. Headquarters.

There are three charts to be issued in the form of pads, covering the following: Reference Fuel Framework; Data Sheet for Supercharge Method; and a Matched Temperature Line Chart for the Aviation Method. These charts are used in considerable quantity depending upon methods applied, and each chart is to be reproduced in letter size 8½ by 11 in. and available in pads of 50 sheets each. The prices are as follows:

Reference Fuel Framework—Single Pads, $2.50; 3 Pads, $6.00; 10 Pads, $17.50.

Data Sheet for Supercharge Method—Single Pad, $1.25; 3 Pads, $3.00; 10 Pads, $7.50.

Matched Temperature Line Chart for the Aviation Method—Single Pad, $2.50; 3 Pads, $6.00; 10 Pads, $17.50.

Copies of The Engine Test Manual are available to members at $6.00 in cloth binding; list price, $8.00. This book was listed on the special Members' Order Blank mailed in December and a good number of orders have been received.

Errata in 1947 D-2 Compilation of Standards on Petroleum

SUBSEQUENT to the printing of the 1947 edition of the compilation of A.S.T.M. Standards on Petroleum Products and Lubricants, several errors have been noted. An errata sheet is being printed for insertion in compilations which have not yet been sold. For the convenience of those who purchased the book and have not obtained errata sheets the changes are outlined as follows:

Viscosity Method D 88–44

page 34—Table of A.P.I. Oil Standards—For the gamma standard, transfer the value "36" sec. in the column for Saybolt Universal viscosity at 210 F., to appear in the column for Saybolt Universal viscosity at 100 F.

Penetration Method D 217 – 47 T

page 150—Fig. 4—Change the internal angle prescribed for the tip of the cone from the present value of "30°" to read "30 ± 1°."

Also change the diameter prescribed for the truncated tip from the present value of "0.015 ± 0.003 in." to read "0.015 ± 0.001 in." and the diameter prescribed for the cone base from the present value of "0.33 ± 0.005 in." to read "0.33 ± 0.002 in."

Thermometer Specifications E 1 – 47

page 552—Table I—In footnote *c* under the column for average temperature of the emergent mercury column, for the thermometer reading of 112 F., change the present value "94 F." to read "95 F." Make the same change in footnote *d*.

page 554—Table I—For the A.S.T.M. Low Cloud and Pour Thermometer 6C–47, change the present value of "—80 C." for the graduation line which is 120 to 130 mm. from the bottom of the bulb to read "—57 C."; likewise for Thermometer 6F–47, change the present value of "—112 F." to read "—70 F."

page 560—Table I—For the A.S.T.M. Saybolt Viscosity (A.S.T.M. Reid Vapor Pressure) Thermometer 18F–39, delete the reference to footnote *h* after the value "2 F." opposite the item "Graduations Numbered at Each Multiple of."

page 564—Table I—In footnote *j* revise the second sentence to read as follows by the addition of the italicized words: "The length of unchanged capillary between highest graduation and expansion chambers shall be *not less than* 10 mm."

Last Call for Papers

ANYONE who is contemplating submitting a paper for presentation at the 1948 Annual Meeting is urged to get in touch with Headquarters immediately in this connection. All offers should be in in time for consideration at the meeting of the Papers Committee which will be held about the middle of February.

With conditions at the printers as they are, it has been necessary to step up the deadlines for receipt of manuscripts, particularly for those which are intended to be preprinted. To be available at all at the meeting, the *manuscript*, quite apart from the *offer*, must be submitted prior to April 26 for preprinting, and for the first distribution of preprints, manuscripts should be available by April 5—preferably earlier. In any event, the offer of a paper should have received consideration by the Papers Committee by the middle of February.

Papers can, of course, be submitted throughout the year either for publication in the BULLETIN or in the *Proceedings*, but such submission would not carry with it presentation at the annual meeting.

Inter-Society Color Council to Meet in March

THE 17th Annual Meeting of the Inter-Society Color Council will be held at the Hotel Pennsylvania, New York City, March 2 and 3, 1948. Tuesday's events include discussion sessions in the morning and afternoon on various problems being studied in the Council's committees involving such topics as color names and terms, specifications, as aptitude tests, blindness studies, textile color matching, etc.

Wednesday morning there is a series of papers dealing with color coordination in industry, and in the afternoon this continues. Four papers are presented in each of the sessions. All those concerned with color are cordially invited to attend these sessions. Copy of the final program notice can be obtained by contacting the Program Committee Chairman, Walter C. Granville, Container Corporation of America, 39 S. Dearborn St., Chicago 3, Ill.

A.S.T.M. participates in the work of the Color Council and has several delegates thereon.

Admiral Hussey New A.S.A. Secretary

VICE-Admiral George F. Hussey, Jr., USN (Ret.), has been appointed Secretary and Administrative Head of the American Standards Association, succeeding Dr. P. G. Agnew, Secretary for the past 28 years. Announcement of the appointment by the Board of Directors was made by Frederick R. Lack, A.S.A. President, who is Vice-President of the Western Electric Co. Dr. Agnew is remaining as Consultant to the A.S.A. Cyril Ainsworth, Technical Director and Assistant Secretary, will continue his activities in the Association as Director of Operations.

Admiral Hussey, who has been chosen to succeed Dr. Agnew, started his Navy career in 1912 with an appointment to the U. S. Naval Academy, and has served in many capacities requiring the highest order of skill and ability. From December, 1943, until his retirement on Dec. 1 1947, Admiral Hussey was Chief of the Bureau of Ordnance of the U. S. Navy Department, where he was in direct charge of the large ordnance production program of the Navy. For his service in this capacity, he was given the Distinguished Service Medal "for exceptionally meritorious service to the Government of the United States," and "the exercise of extraordinary foresight, administrative ability, and forceful leadership in directing the design, production, and supply of weapons."

Mr. Lack's statement pointed out that as head of the Bureau of Ordnance, Admiral Hussey was responsible for its cooperation with industry and with other government departments on standards of mutual concern. Admiral Hussey has won the confidence of industry and Government alike as a result of his brilliant administration of the Ordnance Bureau's program of production for the U. S. Navy.

ASTM Bulletin

JANUARY 1948

NO. 150

NINETEEN-SIXTEEN
RACE STREET
PHILADELPHIA 3, PENNA.

Bulletin No. 150

THE observance of centennials, sesqui-centennials, etc., is a time-honored custom, although the one-hundredth or one-hundred and fiftieth issue of a regularly published news medium or journal may need no particular comment. However, this BULLETIN being No. 150 in the series, it is opportune to point out certain changes that are being put into effect and to indicate some of the things about the future of this publication. Of great significance in the Society's scheme of publication is the continuing flow of technical papers and reports and proposed standards which go into the BULLETIN. In 1947 the total BULLETIN pages aggregated 636 compared with 584 in 1946, and 264 in 1937. A large variety of technical subjects in the field of materials and testing have been covered in recent years and the Administrative Committee on Papers and Publications and the Board of Directors plan that the BULLETINS will continue to carry a goodly proportion of technical papers.

Beginning with March, 1946, the technical material has been segregated following the news content, but not until this current issue has a separate numbering system been used. The pages of technical material will be numbered consecutively throughout the year for ease of reference, to aid in preparing the annual index, and also so that members who may remove the technical material from their BULLETINS for binding separately as a permanent volume can have the pages run consecutively.

The Committee on Papers, in an intensive study of the A.S.T.M. publication scheme, is considering whether it might not be advantageous to have eight issues of the BULLETIN instead of the six that have been issued for the past many years. No change is contemplated, however, in the general setup for some months, and when the plans come to fruition there will be full announcement well in advance.

The BULLETIN is recognized as a very desirable medium by manufacturers and distributors of testing equipment to call to the attention of a large and influential group of individuals and companies the new developments and improved equipment that is available for testing and research.

It is reasonable to assume that a regular review of the BULLETINS as they are received will give members a good idea of major developments in A.S.T.M. activities; will provide some information of other work in materials that would be of concern to our people; and also provide considerable technical material that is of rather current interest.

1948 Nominating Committee

IN ACCORDANCE with the By-laws, providing that the Board of Directors shall select a nominating committee for officers, the Board has considered the report of the tellers, L. Drew Betz, General Manager, W. H. & L. D. Betz, and P. H. Dike, Assistant Director of Research, Leeds & Northrup Co., on the recommendation of members for appointees on the nominating committee and has selected the following committee and alternates:

Schedule of A.S.T.M. Meetings

DATE	GROUP	PLACE
January 19, 20	Board of Directors	Philadelphia, Pa.
January 21	Administrative Committee on Simulated Service Testing	Philadelphia, Pa.
February 3	Philadelphia District	Philadelphia, Pa.
February 2, 3, 4	Committee A-1 on Steel	Philadelphia, Pa.
February 9–12	Committee D-2 on Petroleum	Washington, D. C.
February 9	Administrative Committee on Papers	Philadelphia, Pa.
February 11, 12	Committee B-4 on Electrical Heating and Resistance Alloys	Philadelphia, Pa.
February 16	Papers Committee	Philadelphia, Pa.
February 17	New York District	New York, N. Y.
February 24, 25	Committee D-9 on Electrical Insulating Materials	Dayton, Ohio
February 24	Philadelphia District	Philadelphia, Pa.
February 25, 26, 27	Committee D-20 on Plastics	Dayton, Ohio
February 26	Lower Ohio Valley District	Dayton, Ohio
February 26, 27	Committee C-1 on Cement	Denver, Col.
March 1–5	A.S.T.M. COMMITTEE WEEK	Washington, D. C.
March 17, 18, 19	Committee D-13 on Textile Materials	New York, N. Y.
March 18	Southern California District	Los Angeles, Calif.
Week of March 22	Northern California District	San Francisco, Calif.
April 13	New York District (Meteorological Engineering)	New York, N. Y.
May 20	Western New York—Ontario District	Niagra Falls, Ont.
June 21–25	1948 ANNUAL MEETING AND EXHIBIT OF TESTING APPARATUS	Detroit, Mich.

The three immediate past-presidents, P. H. Bates, J. R. Townsend, and Arthur W. Carpenter, serve as *ex-officio* members of the 1948 Nominating Committee. The committee will meet in March and make nominations for each office—president, vice-president, and five Members of the Board of Directors. The selections by the nominating committee will be announced to the members in the ASTM BULLETIN prior to transmission of official ballots.

NOMINATING COMMITTEE

Members

E. F. Lundeen, Inland Steel Co.
M. A. Swayze, Lone Star Cement Co.
W. T. Gunn, American Petroleum Institute
R. D. Bonney, Congoleum-Nairn, Inc.
H. L. Sherman, Skinner & Sherman, Inc.
G. H. Mains, National Vulcanized Fibre Co.

Respective Alternates

J. R. Trimble, Tennessee Coal, Iron and Railroad Co.
H. F. Kichline, North American Cement Corp.
L. C. Beard, Socony-Vacuum Oil Corp. Inc.
W. T. Pearce Consultant
W. H. Finkeldey, Singmaster & Breyer
H. K. Nason, Monsanto Chemical Co.

New A.S.T.M. District Centering in Washington, D.C.

FOLLOWING discussions with leading Society members and officers in the general area of Washington, D. C., the Administrative Committee on District Activities recommended to the Board of Directors that a new district centering in that area be organized. Accordingly the Board appointed a temporary council with Albert T. Goldbeck, who has been very active in A.S.T.M. affairs, as chairman *pro tem*. It was the function of this temporary group to discuss the mechanics of getting a permanent district organized, including the area to be covered, suggest a name for the district, and especially to appoint a nominating committee which would select a slate of councilors for submission to ballot of the entire membership in the area. This election is now being conducted by letter ballot under the auspices of the Administrative Committee on District Activities, and the accompanying box notes the nominees for the council.

The nominating committee was headed by Past-President A. C. Fieldner, and serving with him were Past-President G. E. F. Lundell, and Messrs. Shreve Clark, F. H. Jackson and T. C. Jarrett.

The area which has been suggested for this new district includes, in addition to the District of Columbia, all of the states of Maryland and Virginia except the eastern shore, North Carolina, and eastern West Virginia, the balance of this state being assigned to the Pittsburgh district.

With the pending organization of a district centering in the Cincinnati-Dayton-Louisville-Indianapolis area, all of the United States east of the Mississippi River except the most southerly states will be in A.S.T.M. districts, which was the aim of the Administrative Committee. The Geographic Section of the A.S.T.M. Year Book identifies the various states and communities in the respective districts. Either in a direct communication or through a detailed article in the BULLETIN, members who now are a part of districts as a result of recently expanded areas, will be advised.

With the organization of the Lower Ohio Valley group there will be thirteen A.S.T.M. districts formally organized. A council elected by the local members is responsible for the administration of the districts. The personnel of the various councils appears on pages 4 to 9 of the current A.S.T.M. Year Book. As indicated, the purpose of these districts is to aid in advancing the interests of the Society in a given locality and furthering the purposes for which the Society is organized. Periodic meetings are held and the councils participate in A.S.T.M. activities in many other ways. They function under a charter granted by the Board.

NOMINEES FOR WASHINGTON (D. C.) DISTRICT OFFICERS

For Chairman: H. F. Clemmer, Engineer of Materials, District of Columbia, Washington, D. C.
For Vice-Chairman (Washington): G. M. Kline, National Bureau of Standards, Washington, D. C.
For Vice-Chairman (Baltimore): A. L. Feild, American Rolling Mill Co., Baltimore, Md.
For Vice-Chairman (Virginia): Shreve Clark, Virginia Dept. of Highways, Richmond, Va.
For Secretary: T. I. Coe, American Institute of Architects, Washington, D. C.

For Councilors:

W. D. Appel, National Bureau of Standards, Washington, D. C.
L. W. Ball, Naval Ordnance Laboratory, Washington, D. C.
A. C. Fieldner, U. S. Department of the Interior, Washington, D. C.
A. T. Goldbeck, National Crushed Stone Association, Washington, D. C.
E. L. Holladay, Office of Chief of Ordnance, Washington, D. C.
C. Merritt Hewett, Mexican Petroleum Corp., Baltimore, Md.
E. F. Hickson, National Bureau of Standards, Washington, D. C.
T. C. Jarrett, Koppers Co., Baltimore, Md.
E. F. Kelley, Public Works Administration, F.W.A., Washington, D. C.
D. E. Parsons, National Bureau of Standards, Washington, D. C.
C. E. Proudley, N. Carolina State Hwy. and Public Works Comm., Raleigh, N. C.
W. H. Reynolds, American Instrument Co., Silver Spring, Md.
L. J. Trostel, General Refractories Co., Baltimore, Md.
Stanton Walker, National Sand and Grave Assn., Washington, D. C.
B. L. Whittier, Mt. Vernon-Woodberry Mills, Inc., Baltimore, Md.

District Meetings in Dayton, Ohio and Philadelphia

DISTRICT meetings are being sponsored in Dayton, Ohio, on Thursday, February 26, and in Philadelphia on Tuesday, February 24, under the auspices of the District Councils in these areas. The Ohio meeting is the first effort of a new district recently authorized by the Board of Directors, in the Cincinnati-Dayton-Louisville-Indianapolis area. The temporary council appointed by the Board, and headed by Chairman *Pro-tem* J. W. Bolton, is taking advantage of the series of technical meetings of Committees D-9 on Insulating Materials and D-20 on Plastics being held in Dayton during the week of February 23; and Howard Nason, of the Monsanto Chemical Co., one of the councilors and very active in D-20 work, is handling local arrangements. The chief address will be given by President T. A. Boyd on the subject, "Research—Everybody's Doing It

Now," and he will be followed by short informal talks providing case histories of research by Robert Burns, Bell Telephone Laboratories, Chairman of Committee D-20, by Dr. Purdy of Lowe Bros., and by Mr. Nason. An informal dinner is to be held prior to the meeting, both events being scheduled for the Dayton Engineers' Club, Jefferson and Monument Streets.

Philadelphia Meeting:

The Philadelphia meeting was postponed from December because of Mr. Boyd's inability to attend due to an accident, but he is now in good shape and will join Mr. E. T. Knight of the Atlantic Refining Co., in a discussion on "Economics of Petroleum" at a meeting at the Franklin Institute the night of February 24. This is taking the form of a President's night. The technical chairman will be Past-President T. G. Delbridge, long associated with Mr. Boyd in the affairs of Committee D-2 on Petroleum Products and now retired from his long-time duties with the Atlantic Refining Co.

All members and committee members in the respective areas will receive by direct mail notices and details of these meetings.

District Meeting in Los Angeles on Building Construction

A MOST interesting meeting was held under the auspices of the Southern California District at the Rodger Young Auditorium in Los Angeles on Monday, December 8. Virgil Rapp, Research Engineer, Department of Building and Safety, City of Los Angeles, spoke on "A.S.T.M. Specifications in Building Construction," and Frank L. Landon, Assistant District Sales Manager for Aluminum Company of America, described "Applications of Aluminum in Building Construction." Approximately 90 were in attendance at the technical session and about 60 at the dinner preceding the session. Arrangements for the meeting were carried out by the District officers, R. B. Stringfield, *Chairman*, Consulting Chemical Engineer; H. W. Jewell, *Secretary*, Pacific Clay Products; and C. E. Emmons, *Vice-Chairman*, The Texas Company.

Mr. Rapp developed a very interesting subject in connection with the use of A.S.T.M. specifications in building construction and pointed out the value of keeping these specifications up to date and the bearing that A.S.T.M. specifications have on preparation of ordinances or other instructions within building departments. His paper elicited many questions from the floor and in general the subject was very well handled.

Mr. Landon included in his talk some slides giving the progressive development of aluminum for construction work, and explained in detail many interesting features which had heretofore been somewhat of a question mark in the minds of construction engineers.

At the conclusion of the talks, the members and guests assembled in separate rooms for further discussion and these separate groups talked long into the night, evidencing an extensive interest in the subject of building construction.

New York Hears about Controlled Heating and Superfast Cooking

AN EXCELLENT meeting on induction heating was arranged by the New York District on December 11 in the Engineering Societies Building, New York. While the spectacular part of the meeting was a demonstration of electronic cooking by A. E. Welch, Sales Manager, Radarange Div., Raytheon Co., Waltham, Mass., involving superfast cooking, the other part of the meeting covering low- and high-frequency electronic induction heating was of equal interest from the industrial standpoint. E. J. Rathsack, Head of the Electronics Division, Allis-Chalmers Manufacturing Co., Milwaukee, described some of the theory and numerous applications of true high-frequency heating. The induction heat can be very carefully controlled and can be made to flow selectively as the frequency is raised. Depending upon the frequency, the heat can be made to penetrate further. Selectivity is one of its chief assets. For deep heating, frequency of a thousand cycles can be attained although a lower cycle will penetrate several inches. In addition to control of depth of penetration, the heat can be confined to certain bands through the concentration of a large amount of heat and power.

Mr. Rathsack, whose talk was supplemented with a film, pointed out that in the soldering and brazing field no particular skill in heating is required. The induction heating has wide applications, for example in the manufacture of small motors, also for compressor housings.

Case hardening can be carried out in a relatively few seconds. There is little warpage since the core of the material is not affected unless machining is required. Examples of uses here involve wrist pins, piston pins, and small parts of that kind.

In melting applications, the tremendous application of power gives excellent results in many cases. The original melting of tungsten, for example, was by induction heat.

The other feature of the meeting, that is, fast electronic cooking, was of much interest to everyone concerned, including the large representation of ladies. Everyone in the audience had a chance to sample some steak or a hamburger or a piece of pie, all of which were processed in periods of time ranging from 10 seconds to a minute and a half. The Radarange is used by a number of hotels and restaurants, and those present had no doubt that it has most interesting possibilities wherever food is prepared.

The District Chairman, Myron Park Davis, introduced the Program Chairman, H. C. R. Carlson, Chief Engineer, Charles Fischer Spring Co., Brooklyn, who had set up the program under the general program committee. He in turn

introduced the Technical Chairman, L. L. Wyman, of the General Electric Co., Schenectady, well known to large numbers of A.S.T.M. members. Mr. Wyman tied the meeting features together in good fashion.

It was announced that the next meeting of the Council would be held on February 17, when Dr. Walker, Bell Telephone Laboratories, will describe his notable research work in growing crystals for communication uses.

A.S.T.M. District in Chicago Production Show

THE A.S.T.M. Chicago District Council is arranging to sponsor a technical session during the forthcoming Chicago Production Show, March 22–24, inclusive. This annual event is under the auspices of the Affiliated Technical Societies of Chicago of which A.S.T.M. is one of the member groups. While the exact subjects to be covered at the A.S.T.M. session have not been finally decided, D. L. Colwell, Apex Smelting Co., chairman of the program committee, together with Messrs. J. J. Kanter, Crane Co., and G. E. Stryker, Bell & Howell Co., District Chairman and Secretary respectively, are tentatively planning to have three papers—one in the field of steel, another on plastics, and a third dealing with die castings.

All A.S.T.M. members and committee members are cordially invited to attend this Production Show.

March West Coast Meetings

DURING March, President T. A. Boyd and Executive Secretary C. L. Warwick will visit the Southern and Northern California Districts, and will participate in technical meetings being arranged in Los Angeles and San Francisco under the auspices of the respective A.S.T.M. councils. The first meeting is in Los Angeles on March 18, and the second one in San Francisco on March 25. This latter is a joint meeting with the San Francisco Chapter of The American Society of Mechanical Engineers, while the Los Angeles meeting is being arranged jointly with the local section of the Society of Automotive Engineers.

At each of these meetings President Boyd will give a talk along the general lines of research developments in materials and mechanisms. The Executive Secretary will discuss A.S.T.M. activities of particular interest to the groups participating. Further details of the meetings are being mailed directly to all A.S.T.M. members in the respective districts.

Research Problems in Plastics Requiring Investigation

Subcommittee VIII on Research of Committee D-20 on Plastics, has compiled a list of research problems which should be suitable for investigation by college and university graduate students. The solution to these problems would not only advance knowledge in the field of plastics, but would also afford valuable training to students contemplating entering this field subsequent to completion of their scholastic work.

Subcommittee VIII stands ready to assist educational institutions undertaking these investigations by offering the assistance of small advisory committees composed of experienced D-20 personnel. These committees would act in a consulting capacity and such assistance should greatly expedite the solution of the problems listed.

While the members of Committee D-20 who submitted the research problems, tabulated below were asked to indicate the urgency of each, it was found on careful consideration that it was difficult, if not impossible, to assign ratings which reflected the importance of any specific problem to the industry as a whole.

Group A: Behavior of Plastics Under Mechanical Stresses with Time and Temperature as Variables, that is, Stress versus Strain Relationships

I. Study of the physics of behavior of plastics under impact with the object of relating behavior under high rates of stressing to that under the lower rates encountered in ordinary testing.

More specifically:

(*a*) What is the effect of "stress raisers" such as holes and notches? What is the skin or surface effect?

(*b*) Will impact tests in tension yield more information than the conventional bending type of impact test?

(*c*) Can impact testing be sufficiently closely related to "static" testing so that behavior under impact can be predicted from stress-strain data under low rates of stressing?

(*d*) Can the behavior of plastics at low temperatures be related to that at high velocities closely enough so that one variable may be substituted for the other?

(*e*) What is the effect of repeated impacts and can the behavior of plastics under repeated impact be predicted from data obtained by conventional methods?

II. Studies of plastics under tensile, compressive, flexural, and torsional stresses with the object of adjusting such variables as geometry of the specimen, points of load application, and rates of stressing, so that standard tests may all be made under comparable conditions.

Specific problems of this general type are:

(*a*) What l/d ratios in compression lead to failure without buckling?

(*b*) What is the ideal geometry for compression specimens?

(*c*) Development of a standard one-piece test specimen for determination of properties of molded materials.

III. The development of standard techniques for:

(*a*) Determining the flexibility and "Hand" or "Drape" of thin plastic films at various temperatures.

(*b*) Measuring tear resistance of thin plastic films.

IV. Systematic studies of the flow properties of the various resins with special attention to rates of shear, pressures, and temperatures in the ranges encountered in molding and extrusion. This information should lead to a better understanding of flow properties and to flow tests which better characterize the flow properties.

V. Development of a method for describing the creep of plastics such that from a few measurements the rate and amount of deformation can be predicted. This method, to be most useful, should be applicable over wide temperature ranges and should permit prediction of deformation under low loads over long periods of time. Correlation of creep and second order transition temperatures might indicate temperature at which marked changes in creep characteristics occur.

VI. Studies of the effects of reinforcing

(*over*)

pigments on the physical and chemical properties of plastics.

Group B

Studies of the wear abrasion, scratch, or mar resistance of plastics with the object of relating these properties to other mechanical properties or to the detailed chemical or physical structure.

Specifically, a study might be made of the energy required to scratch, indent, abrade, or otherwise deform the surfaces of plastics.

Group C

Studies of the permanence of plastics in various environments with the object of learning what chemical and physical changes occur in plastics as a result of aging, of elevated temperatures, of sunlight, and of weathering.

Specific problems of this general type include:

(*a*) Studies of the time after molding required for molded articles to attain their final dimensions, and of methods for shortening this time.

(*b*) Development of an accelerated weathering device which correlates fully with outdoor exposure; to be most useful, such a device should accommodate a number of specimens each of which should be large enough for several physical tests and the device should require a minimum amount of attendance —not more often than once in 24 hr.

(*c*) Development of physical or chemical methods for determining or estimating the degree and course of deterioration of plastics under various environments. A method for detecting the very early onset of such deterioration would be helpful in shortening the time required for studies in permanence.

Group D

Studies aimed at the compilation of data which are not currently available.

(*a*) Measurements of specific heat over temperature ranges which include molding and extrusion temperatures.

(*b*) Measurements of thermal conductivity of solid and of "foam" types of plastics. Correlation of heat transfer properties with deterioration of physical and electrical properties after exposure at high temperature over prolonged periods would be desirable.

(*c*) Measurements of the sound absorption properties of solid and of "foam" types of plastics.

(*d*) Measurement of the "second order transition" temperature for the various plastics; correlation of these data with other physical properties.

(*e*) Resistance of plastic materials to the increase of marine growth or fouling as a result of long exposure to sea water immersion.

(*f*) The effect of long-time immersion of plastic materials in various hydrocarbon oils on their physical properties.

(*g*) The establishment of relationships between maximum ser ice stress and operating temperature for plastics.

Group E

Studies of methods for characterizing the chemical and physical structure of plastic.

Specific problems of this type are:

(*a*) Development of methods for the identification of plastics including plasticizers and other components.

(*b*) Development of standard methods for the determination of molecular weight of polymeric materials.

(*c*) Development of methods for characterizing molecular weight distributions in polymers.

(*d*) Development of methods for estimating the degree of cure of thermosetting resins.

(*e*) Development of standard methods for determining compatibility of plasticizers, softeners, lubricants and the like, with various resins, cellulosic derivatives etc.

Group F

Development of methods for evaluating coated fabrics.

Specifically, methods are needed for determination of:

(*a*) Adhesion of plastic coatings to base fabrics.

(*b*) Mildew resistance.

(*c*) Resistance to "snagging."

(*d*) Loss of plasticizer by evaporation, exudation, mildew, stress exudation, skin and hair oil extraction.

(*e*) Hydrolysis of plasticizers in presence of resin decomposition products, pigments and fillers as evidenced by odor.

Group G

Development of rapid test methods, the results of which could be qualitatively related to A.S.T.M. standard test methods.

Submitted by C. R. Stock,
Secretary, Subcommittee VIII

Professor McLaren to Speak at Adhesives Committee Meeting

It is announced that the program of meetings of Committee D-14 on Adhesives in Washington, during the A.S.T.M. Committee Week, has been augmented by a talk to be given by Professor A. D. McLaren, Department of Chemistry, Polytechnic Institute of Brooklyn. The subject of Professor McLaren's address will be "The Fundamental Properties of the Adhesion of High Polymers to Cellulose." This topic should be of considerable interest to all members in the field of adhesives, plastics, and possibly paper and textiles. The talk is now scheduled for Thursday afternoon, March 4.

DISTRICT PAPERS

Editors Note:—

The papers published in condensed form below were presented at meetings sponsored by A.S.T.M. Districts in Buffalo and Philadelphia. Mr. Bouvet's paper was part of a technical session on Textile Fibers, other contributions on this subject having appeared in the December Bulletin. The papers by Messrs. Lutz and Barton were given in what is intended to be the first of a series in various districts, to give those interested a bird's eye view of a particular industry and some of the significant recent developments. It is believed that one of the aims of district meetings is to provide members with pertinent information and data in the field of materials which may or may not be specifically related to a member's own daily work. There is no question that while member A may be primarily concerned with the field of rubber, for example, and member B with steel, in this day and age of composites and overlapping of materials interest, it behooves all of us to have as broad a knowledge as possible. The Administrative Committee on District Activities will be glad to have comments on this type of meeting which is exemplified by the accompanying material presented by Messrs. Lutz and Barton. As the "pioneers" in this endeavor we wish to compliment them on their willingness to cooperate.

Paint—Servant of Industry[1]

By W. H. Lutz[2]

The manufacture of paint was among the first discoveries of mankind. Every tribe and every race of man have used paint in some form to adorn themselves or their possessions. It was not until man began to build wood houses in the New World that he came to appreciate the protective value of paint and coined the slogan, "Save the surface and you save all."

[1] This is a somewhat condensed version of a paper presented at a meeting in Buffalo on November 18, 1947, sponsored by the Western New York-Ontario District.

[2] Technical Director, Pratt & Lambert, Inc., Buffalo, N. Y.

The paint industry today is big business. There are 1400 paint manufacturers in the United States and their combined sales in 1946 amounted to 900 million dollars. Behind these sales figures lie centuries of slow, paintstaking progress.

While the oldest painting in existence, in a cave in northern Spain, was made from 10,000 to 50,000 years ago, there was little improvement in paint techniques until the Middle Ages when the practice of oil painting was established, about the year 1400.

The manufacture of paint as a commercial commodity did not begin until about the Civil War period in this country. Prior to that time, each painter had tediously ground out his pigments on a stone slab. The first factory-made paint was produced on a stone mill borrowed from a neighboring flour mill. Most modern paints are made in either roller or ball mills.

A roller mill consists of a bank of two, three, or five steel rolls turning in opposite directions and at different speeds. Pigment and vehicle are kneaded together by the squeezing and shearing action of adjacent rolls.

A ball mill is a steel drum, partially filled with flint pebbles or steel balls about the size of golf balls. The mill turns like a concrete mixer. Brigham Young, the Mormon leader, is credited with using the first ball mill for grinding paint. He placed a cannon ball inside an iron kettle mounted on a turntable. This produced the same effect as in a modern ball mill.

Since the ball mill requires no attention from the time of loading until discharge, it is becoming a favored piece of equipment. A roller mill, however, will produce higher gloss finishes than either ball or stone mills.

The common term "grinding" is really a misnomer, since the main function of paint mills is thorough wetting of the pigment by the vehicle.

Not until the 13th century was painting recognised as a trade or craft, and it took another seven centuries to develop the paint spray gun, which appeared in 1911. Its labor-saving features were quickly accepted and industrial painting on a mass production scale really began.

The spray gun was the invention of an obscure and erratic country doctor named de Vilbiss. Dr. de Vilbiss invented an atomizer for dosing nose and throat tissues. This was the forerunner of the perfume atomizer and the paint spray gun. All work on the same principle.

Faster painting methods brought a demand for faster drying finishes. This led to the development of lacquer, "4-hr." enamels, and finally to finishes which dry in a matter of minutes at elevated temperatures.

Raw Materials:

The principal change in paint since the beginning of time has been in the vehicle portion. We still use the earth colors and bone black that were used in the cave drawings, although many new pigments have been developed and they have contributed to the advance of paint technology.

What are some of the raw materials that enter into the production of paint and varnish vehicles and where do they come from?

A large paint factory carries an inventory of over 500 different raw materials. These materials are gathered from every corner of the globe. Fully half of the materials fall into two general classes—vegetable oils and resins. For vegetable oils, the paint industry depends upon international agriculture, the crops of which are affected by wars in Asia, politics in Argentina, and droughts in this country. For resins, it depends upon native labor in far-off Indonesia, coke ovens in Pittsburgh, and naval stores in Georgia. For other raw materials, it depends upon mines, oil wells, and chemical plants everywhere.

Vegetable oils belong to a class of substances known commercially as fats and oils. Some fats and oils, like linseed oil, dry to a hard film and make good paint; others, like cottonseed oil, never dry or harden and are used in soap and foodstuffs. An oil "dries" if its molecular structure permits it to absorb oxygen from the air.

The paint industry consumes more than 500,000,000 pounds of fats and oils each year. About 70 per cent of this amount is used in the form of linseed oil. This is the most important single raw material used by the industry. It is produced by squeezing the oil from flaxseed. Flax, the common ancestor of both linen cloth and paint, is cultivated in one way to yield linen fiber and in another way to yield an abundance of seed. Flax is grown extensively in the United States, Canada, Argentina, and Russia. In the United States, two states—North Dakota and Minnesota—provide about three-quarters of all the flax acreage. In normal times, 15 per cent of the linseed oil used by the paint industry in this country is pressed from Argentine flaxseed.

China wood oil or tung oil ranks second to linseed oil in paint-making importance. Marco Polo is said to have been the first to name the oil "China wood oil" during his travels in Cathay in the 14th century. Tung oil has protected Chinese junks for centuries, but in the United States it has been an important paint material for less than fifty years. The work "tung" is Chinese for heart and apparently refers to the heart-shaped leaves of the tung tree. Tung oil is derived from the nuts of the tung tree; these nuts look something like russet apples.

The supply uncertainties and economic hazards associated with the importation of tung oil were early recognized and tung nuts for growing experiments in this country were widely distributed but it remained for a Florida cemetery to grow the first tung tree to maturity in the United States. Today, there are thriving groves of tung trees throughout the Gulf states, but these groves provide less than 5 per cent of the normal requirements of the paint industry.

Tung oil is normally more expensive than linseed oil, but it dries faster and is more water resistant. In wrinkle finishes, tung oil is the ingredient responsible for crinkly texture.

Linseed oil and tung oil are drying oils. The paint industry also uses castor oil, a nondrying oil, and soya oil, a semidrying oil. Castor beans are grown in Brazil; soya beans are a domestic crop.

In recent years, castor oil has moved out of the medicine cabinet into the paint industry's storage tanks. It its original state, castor oil is of little value in paint, but chemists have been able to convert it into a useful drying oil, known as dehydrated castor oil. Modified soya oil too can be used as a drying oil. These modified oils are frequently used as substitutes for linseed oil and tung oil.

Oil may be used alone as a paint vehicle and is actually used that way in exterior house paint, the vehicle of which is largely linseed oil. Straight oil vehicles have several disadvantages, however—especially from an industrial standpoint. Paints made from them dry slowly, level

poorly, and have only moderate gloss. These disadvantages can be overcome by combining resin with oil in the form of varnish. Varnish can be used as a clear coating or as a vehicle in making enamel. An enamel is merely a paint which dries with exceptional gloss and smoothness.

A Typical Varnish:

It may be of interest at this point to trace through the manufacture of a typical varnish. First, oil and resin are measured out in the proper proportions in a varnish kettle. The ingredients do not combine at room temperature but have to be reacted at temperatures between 450 and 600 F. Varnish is cooked at this temperature until the molten mixture "strings" as it drains from the stem of the varnish maker's thermometer. After the varnish "strings," it is allowed to cool and is then thinned to proper consistency with turpentine or mineral spirits. Next, drier is added. Driers are metallic soaps of lead, manganese, and cobalt. They serve as catalysts and accelerate the drying and hardening of paint and varnish. The varnish is now filtered through a press or passed through a centrifuge to remove dirt and undissolved matter. It is finally pumped into bulk storage tanks, where the varnish gains clarity and brilliance as it ages and as the less soluble ingredients sludge out.

In varnish, oil makes the film tough and elastic. Resin makes it dry faster and harder and gives it gloss and body. The proportion of oil to resin, and the type of each ingredient, determine the qualities of the finished varnish. Varnishes containing a large proportion of oil are called "long oil" varnishes; those containing a small proportion of oil are called "short oil" varnishes. "Long oil" varnishes are more durable than "short oil" varnishes but the latter dry more positively and are used mainly in interior and industrial finishes.

Resins:

The resins used by the paint industry are usually divided into two classifications—natural and synthetic.

Nature has provided a variety of resins, but rosin is one of the few natural resins familiar to the public. It is probably best known for its association with violin bows and the prize ring. It is derived from the sap of the longleaf southern pine. The sap is collected in much the same manner as maple sap but instead of being boiled, pine sap is distilled. The residue is rosin; the distillate is turpentine.

The best natural resins come from Africa, Malaya, New Zealand, and the East Indies and are known as fossil resins. They are the hardened (or fossilized) secretions from trees that lived hundreds of years ago. The resins are dug from the earth long after the vegetation from which they originated has decayed. Rosin varnishes are cheap but are brittle and whiten in contact with water; fossil resin varnishes are tougher, more serviceable and more water resistant. Fossil resins, however, have been largely supplanted by synthetic resins because the latter are uniform and are not dependent upon gathering agencies and ocean shipping facilities on the other side of the globe.

The first man-made resin to attain widespread use was ester gum and it is still popular. Ester gum is made by reacting rosin with glycerin. Ester gum bears little resemblance to rosin for it produces tough and water-resistant finishes.

Synthetic Resins:

Ester gum is man made, but it is not generally regarded as a synthetic resin. The paint industry usually defines a synthetic resin as one which is made from nonresinous organic chemicals. There are literally dozens of synthetic resin types, each with its own specialized applications, but only four types are produced in substantial tonnages. They are the phenolics, the alkyds, the amino resins, and the vinyl resins. In 1946, 330,000,000 lb. of these four resin types were consumed in paint.

In discussing synthetic resins, it is difficult to tell where the paint industry leaves off and the plastics industry begins. The synthetic resins used in paint are blood relatives of the molding and casting compounds consumed by fabricators in the plastics field. As much as 38 per cent of all plastic materials are used in protective coatings; only 25 per cent are used for molding and casting.

Phenolic resin was the first synthetic resin. It is popularly known as "Bakelite," but "Bakelite" is the trade name of resins made only by the Bakelite Corp. The first phenolic resins were manufactured by reacting phenol (carbolic acid), a germicide, with formaldehyde, an embalming fluid. Today, simple phenol has been largely replaced by complex phenols and substituted phenols and the resins are frequently modified with rosin. When phenolic resins were introduced in 1910, the paint industry made several abortive attempts to use them in place of fossil resins, but it was not until 1926 that they were widely and successfully used in paint. Their acceptance at that time paralleled the overnight growth of the lacquer industry which had created a demand for fast-drying finishes. Thus the first appeal of phenolic resin was its ability to produce fast-drying finishes. In addition, phenolic finishes are tougher and far more alkali and moisture resistant than finishes containing most other resins. Industrial examples of the use of phenolics are provided by interior food can coatings which must withstand pasteurizing or cooking treatments; and collapsible tube enamels requiring resistance to alkali.

Alkyd resins are comparative newcomers, but they have won a very important place. An alkyd is defined as the reaction product of a polyhydric alcohol, such as glycerin, and a polybasic acid or anhydride, such as phthalic anhydride. The earliest alkyds were simply glyceryl phthalate resins, but most commercial resins of today are modified with vegetable oils, oil acids, or other resins. Phthalic anhydride is obtained from naphthalene, which is a coal-tar derivative.

As a class, alkyds are characterized by good adhesion, pale color, and unusual exterior serviceability, including good gloss and color retention on exposure. Probably the most extensive use of alkyds has been in the automobile field. The finish on Ford cars is a familiar example. Alkyd finishes are also widely used for the finishing of metal furniture, fixtures, mechanical devices, and automotive parts.

The alkyds have been combined within the past few years with amino resins to yield unique industrial finishes. In these finishes, the alkyd serves primarily as a plasticizer for the amino resins, which by themselves are very hard and brittle and lack adhesion.

There are two main classifications of amino resins—the ureas which are made by condensing urea with formaldehyde and the melamines which are made by reacting cyanamid with formaldehyde.

Urea-alkyd and melamine-alkyd finishes are hard and mar resistant. Unlike the finishes thus far discussed, they will not air dry but must be cured at temperatures ranging between 225 and 350 F. They make exceptionally fine white enamels which can be baked at these temperatures without discoloration. These enamels have been widely used on household appliances, such as stoves, washing machines, and refrigerators. This fact is ample evidence of their mar resistance, toughness, and color permanency.

The vinyl resins constitute a large and important group of synthetics. They are derived by reacting acetylene with acetic acid and hydrogen chloride. The vinyls were first used commercially as the sandwich spread in making laminated safety glass. This fact indicates two of their dominant characteristics, namely, water-white color and excellent color permanency. They are also flexible, resistant to corrosive chemicals, and, in addition, are odorless and tasteless—qualities which made them popular as coatings on the inside of prewar beer cans. The vinyl resins are costly, rather difficult to apply, and require baking for maximum adhesion. These disadvantages did not discourage an enormous wartime usage in the production of army raincoats and other fabrics. They

are currently finding favor in the fabric and paper coating fields.

Lacquer:

There is one remaining widely used type of finish, and that is lacquer. Though it is being discussed last, it is by no means least important. Lacquer differs from most other coatings in that it dries solely by solvent evaporation. In contrast, oil, varnish, and synthetic resin coatings dry by chemical change, that is, oxidation or polymerization. Lacquer consists of a solution of nitrocellulose in organic solvents, together with modifying agents, such as plasticizer and resin. Nitrocellulose looks like ordinary cotton and is made by reacting cotton linters with nitric acid. Lacquer dries fast and produces a hard, tough film, but it has the disadvantage of softening and sometimes redissolving in alcohol and certain other organic solvents. This factor is of importance when lacquer is used to finish table tops and dresser tops on which liquor or perfume may be spilled.

Original Camouflage:

The public ordinarily associates lacquer with automobiles, but clear lacquers were used on metal long before the automobile was conceived. Lacquer traces its commerical history back to the brass bed era. Brass beds originally were lacquered in order to prevent tarnishing, but ultimately another motive developed. Someone discovered that low copper content brass could be made to look like more expensive high copper content brass by coating it with lacquer tinted with yellow dye. This was one of the first commercial uses of paint as camouflage. Another case of camouflaging is provided by blue razor blades and clock springs, both of which are given the color of highly tempered steel by lacquer containing transparent blue pigment.

Clear lacquers are used in preference to varnish on decorative metals because they do not alter the appearance of the metal to any great degree. Lacquered silverware illustrates the advantage of lacquer in this respect.

Paints:

People frequently want to know what type of paint is best—whether it is lacquer, alkyd, phenolic, or some other type of coating. There is no one best all-purpose paint. Each paint type has its own virtues and limitations.

Industrial paints are ordinarily custom built to meet the special requirements of the industrial user. If one particular characteristic is all-important, it can usually be built into paint—but only by making sacrifices in other qualities.

Paint is a peculiar commodity in that the user buys it in liquid form but expects certain standards of dry film performance. The paint manufacturer may carry on extensive research and produce a finish of the highest quality, but the moment his paint reaches the user, it is at the mercy of the person who applies the paint.

Surface Preparation and Applying:

Two factors are almost as important as paint quality in producing a good paint job. They are proper surface preparation and proper application. Proper surface preparation includes the cleaning, sanding, priming, and surfacing operations on wood and metal prior to the application of finish coats. Proper application involves the selection of a suitable painting method and skill in using that method. Industrial finishes are usually applied by spray, dip, roller coat, or knife methods.

About 85 per cent of all industrial paints are sprayed. Spray painting is the most flexible method of applying industrial paint for it can be adapted to any type of article. Electrostatic spraying attained considerable importance during the war years. In this process, the paint particles after leaving the spray gun pass through an electrical field where they become charged. The charged particles are attracted to the work which is grounded, and overspray is minimized. The process is very effective for coating irregular, spindly objects like wrought-iron garden furniture where large spray losses usually occur.

Next to spraying, dipping is probably the most popular industrial painting method. Dipping is best adapted to relatively small objects, like tools and towel bars, which have geometrically uniform shapes. The proper suspension of objects during the draining and drying period requires considerable ingenuity in order to keep flow marks and drips inconspicuous. Dipping always produces greater film thickness at the bottom of an object than at the top, and it invariably leaves a "tear drop" at the point of drainage.

In gasket dipping, the painted object is fed through a flexible collar to remove excess paint. The applicability of gasket dipping is limited to long objects having a uniform cross-section such as enameled wire, broom handles, and pencils.

A roller coating machine looks like an enlarged household wringer. The object being finished is fed between the rollers, one of which applies the finishing material. Roller coating is limited to flat sheets and is widely used by the metal decorating industry. A modified roller coater is used for painting collapsible tubes.

Knifing is largely confined to cloth, paper, and fabric coating. In this method, the surface being coated is pulled under a rigid bar or knife, behind which is fed a supply of coating material. The knife spreads the coating uniformly.

Novel Paint Uses:

There are many novel uses of paint. Manufacturers of cheap jewelry consume considerable paint in the form of so-called pearl essence lacquers. Pearl essence is a by-product of the fishing industry. Fish scales contain an organic substance which when dispersed in lacquer produces a pearl-like, opalescent effect.

Cheap taffeta is given a rustle like the richest of silks by stiffening it slightly with lacquer.

Artificial fur is produced on novelties and on toy animals by a so-called flocking operation. A coat of colored enamel is applied and is then dusted with short textile fibers while the film is still wet. After the adhesive dries out, the finished object feels and looks like suede.

Hammered metal finishes have become extremely popular in recent years. Originally they were produced by applying paint and then spattering the wet film with thinner. Now they can be produced in a single operation by applying the finish in a poorly atomized state.

Playing cards are given the slippery feel that is needed for shuffling and dealing by a coat of lacquer. This lacquer must be moisture and alcohol resistant.

Few people realize that new rubbers and overshoes owe their shiny appearance to varnish. The varnish is an especially elastic and durable one and it is applied on the uncured rubber while the latter is held in shape in its mold. The varnish is baked in the same operation that cures the rubber.

One interesting wartime aircraft paint development warrants brief mention. At the beginning of the war, all of our planes were camouflaged with low-gloss, nonreflecting paint. The paint film weighed from 75 to 80 lb. in the case of a 4-engined plane like a B-17 Flying Fortress. When the military initiative passed into our hands in the later stages of the war, the importance of defensive camouflage was superseded by a need for increased plane speed and greater range. By replacing low-gloss camouflage paint with smooth, glossy paint, air resistance was decreased, the paint film weighed less, and top speeds were increased 1 to 2 per cent. This increase in speed is not spectacular from a percentage viewpoint, but it frequently meant the difference between the success and failure of long missions.

Paint is synonomous with color and, as you know, color is related to heat. Dark-colored paints absorb heat; light-colored paints reflect heat. Professor Piccard, the Swiss balloonist, verified this fact on his first flight. He had painted his balloon gondola black and at an altitude of several miles above the earth, the temperature inside registered 100 F. although the outside temperature was −72 F.

The same idea is applied in reverse in

the painting of petroleum bulk storage tanks. These tanks are painted white aluminum, or other light color in order to reflect heat and thus minimize the evaporation loss of materials stored in the tanks.

Whether paint is applied on a gasoline storage tank, a washing machine, or a toy, it serves two broad purposes—decoration and protection. Paint literally protects the wealth of this country. Without paint, metal rusts and wood decays. Experts have estimated that paint saves the American public 3½ billion dollars annually in preventing needless destruction of wood and metal. But industrial paint makes an added contribution. It brings happiness to millions of Americans in the form of colorful furnishings and appliances, eye-catching gadgets, and bright hued, shiny automobiles.

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Recent Development in Portland Cement[1]

With a Thumbnail Sketch of the Industry

By J. F. Barton[2]

SOME HISTORY AND DATA:

The first American portland cement was made by D. O. Saylor in 1872 at Coplay, Pa. This plant is still in operation. Today we have 151 active plants located in 33 of our 48 states.

In 1880 the production of portland cement in the United States was 42,000 barrels compared with the 1946 production of 163,805,000 barrels. The production rate in 1947 through the month of May was 74 per cent of rated capacity. The unprecedented demand will result in production of well over 200,000,000 barrels for 1947.

To appreciate the magnitude of the job being accomplished, consider the tonnage of basic raw materials that are mined or quarried, and processed in order to manufacture 163,805,000 barrels of portland cement. They are:

Calcareous materials—mainly limestone and cement	36,905,000 tons
Argillaceous materials—mainly shales, clays, and blast furnace slag	11,950,000 tons
Fuel—mainly bituminous coal	7,000,000 tons

Oil and gas fuels are not included here, although they are important in the Southwest for cement burning. It requires 600 to 615 lb. of raw materials to produce 376 lb. of portland cement clinker. Coal consumption will average 100 lb. per 376 lb. of clinker, using 13,000 Btu. fuel. Other materials, such as grinding aids and air-entraining agents, amount to several million pounds each year. These additives range in cost from 6 to 18 cents per lb.

Much technical skill and close manufacturing control go into the manufacture of cement. The raw materials are processed in a continuous operation 24 hr. per day and flow continuously through the process of burning, grinding, and storage in large bulk silos.

The cost of a cement plant based on prewar prices varies, depending on size, from two to six million dollars. The United States Geological survey is credited with the following statement, "That price of the product sold from mills involving the above capital investments is so low that one could not scrape the free sand from the gutters of our streets and highways at much less cost per pound."

PORTLAND cement development ties in directly with its use in concrete and in this respect specifications and testing methods are important.

Prior to 1934, there were two basic types of portland cement used in general concrete construction—standard A.S.T.M. C 9 cement and high early strength cement. Today A.S.T.M. specifications provide for five basic types of portland cement and modifications of types 1 and 2, the air-entraining cements. The background and development of the modified or, better termed, air-entraining cements are of much interest. A.S.T.M. Committee C-1 on Cement has played an important role in guiding developments.

In 1934, the U. S. Bureau of Reclamation requested bids on portland cement for use in the Boulder Canyon Project under their specification No. 566. This cement, termed "low heat," was the forerunner of type 2 moderate heat of hydration cement of A.S.T.M. Specifications C 175. With such a great mass of concrete to be placed in the Hoover Dam, the engineers readily saw the need for a cement that would, upon hydration, develop lower heat of reaction than was possible with the then standard gray portland cement. The volume change potential that could result from excessive heat of hydration in a mass of concrete as large as Hoover Dam was determined as sufficient to cause internal disruption by expansion almost to the point of exploding the mass, hence the desirability for low heat of reaction cement and the subsequent development of our present-day moderate and low heat cements.

Even though the dam was built with low heat cement, refrigerating pipes were constructed into the dam and cooling brine was pumped through to control the cooling of the mass. The low heat cement, however, lowered the cost by lessening the heat generating problem. This was one of the first cement specifications that gave recognition to cement compound composition and made them part

[1] Abstract of a paper presented at the Buffalo District Meeting on November 18, 1947.

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of the requirements. A.S.T.M. Committee C-1, with its diversified personnel, was a logical group to study and evaluate the theories which led to promulgation of the specification. The cement was recognized as being low in aluminates. The alumina phase of cement compounds has been under examination by many of the laboratories represented on the committee for some time as a possible clue to eliminating some of the unstable compounds of portland cement.

About this time there was increasing evidence of scaling of concrete pavement surface from repeated application of calcium and sodium compounds for ice removal. There was laboratory evidence that the low-alumina cements were more resistant to this condition of service. The work that followed has developed our knowledge of the four major compounds known to exist in well-burned portland cement and the relation of these major compounds to cement and concrete durability. They are not the final answer for cement and concrete durability, however.

The Department of Public Works of the State of New York has pioneered in concrete-surface durability research and studies. It was through construction methods, aggregate characteristics and laboratory analysis of cements used in pavements throughout the state that gave us our first clue to air-entrained cements. One Hudson Valley cement stood out above all others in durability rating. Chemically, it paralleled the low-aluminate cement for Hoover Dam but it produced a lighter weight concrete. After considerable study it was learned that this cement entrained more air than other cements of the same composition. The reason was traced to some lubricating oil from the bearings of the grinding unit being ground into the cement. The amount was small, yet sufficient to give a special property to this cement.

This discovery set off a series of investigations that are continuing. We have a general understanding and many data on the successful usage of air-entraining cements.

In the period between 1934 to 1941 there were rapid and important developments in cement specifications resulting in the adoption of the five types of cement as standards of the Society in 1941. The acceptance of air-entraining cement as an A.S.T.M. Tentative Specification (C 175) came in quick succession.

With changes in portland cement specifications came improvements in the science of cement manufacturing and testing. The meaningless 200-mesh sieve test for fineness was replaced with the more scientific Wagner turbidimeter which utilizes the photoelectric cell or electric eye and microammeter to measure cement surface area.

Under the impetus of higher fineness requirements, the industry has almost universally adopted air separators in closed circuit with grinding units to produce a more uniform fineness and much better particle size distribution. With the turbidimeter we can accurately measure particle sizes ranging from 7.5 microns to 65 microns. Values obtained by the turbidimeter are expressed as surface area in terms of square centimeters per gram. This tool has made it possible to set up better routine control on cement grinding. Work is now under way in a subcommittee of Committee C-1 toward measurement of particles finer than 7.5 microns.

The Society acted quickly to follow the lead of the portland cement industry in adopting the autoclave test for soundness. The industry acted voluntarily to put this into effect in February, 1937. It has provided a better gage of volume change which is caused by the hydration reaction in cement. The older pat test was not dependable.

Better knowledge of the reactivity of some of the oxides in portland cement, principally calcium oxide and magnesium oxide, showed that stability of these oxides has an important influence on cement soundness. The autoclave test provides an excellent tool for determining the degree of stability.

Committee C-1 activity in developing and standardizing chemical tests for free or uncombined lime has aided materially in the development of more uniform burning of cement. Work now under way on the alkalies in cements and their activity with reactive aggregate promises to be another major step toward the solution of the concrete durability problem.

Research on the influence of gypsum on the hydration and properties of portland cement pastes by William Lerch showed that the amount of gypsum required to properly retard setting reaction of cement varied with the amount of compounds found in each type. A more liberal specification for SO_3 contents is another important step in promoting volume change stability.

Experience with air-entraining agents and tests developed to determine their reactivity in cement has given us the "know-how" to produce a uniform dependable product. The user of air-entraining cement today need not fear radical variations in air content, such as was experienced during the early development of these products.

Types I and II cements are being treated with air-entraining agents with equal degree of success. Some work has been done on treating type III cement with air-entraining agents, but data are not yet available. Air-entraining cements have made it possible to build good concrete with poorly graded aggregates without fear of placement troubles and mix segregation. The use of blast-furnace slag as aggregate in concrete has been increased through the lubricating property of air-entraining cement. This statement is generally true for all angular aggregates. Fear of segregation of concrete components during placement in close form work or where reinforcing steel acts as an obstacle in concrete placement is to a great extent eliminated by the use of air-entraining cement.

Early use of air-entraining agents was confined to intergrinding with the cement in sufficient quantity to produce, when used in concrete, 3 to 5 per cent of air. There is now a strong trend to add air-entraining agents directly to the concrete at time of mixing where the amount of agent can be readily varied depending on air development.

If this trend continues, it will simplify the congested storage problem for different type of cement.

There is another recently developed approach to air entrainment in concrete. It can hardly be called a cement development, yet the material adds valuable properties to concrete. The material, a finely ground blast-furnace water granulated slag, has delayed cementing properties in itself with the ability to hydrate normally in the presence of portland cement. Such a slag has been classified for a long time as an artificial puzzolana. An air-entraining agent when interground in proper amount with this puzzolana material will effect a close control of the air when the puzzolana is used as a replacement for part of the portland cement. Puzzolanas are not new, since the ancient Romans used natural puzzolanas in the form of volcanic ash to build enduring concrete. Puzzolana activity in cement is under investigation and it promises to lead us to the development of some very important new types of cement.

Although I have stressed air entrainment, each cement has a proper place in our economy. It is for the user to understand better where and when to use the various types of cement that are made available to him.

With reference to this general statement, I wish to call attention to the Concrete Experimental Farm of the Portland Cement Assn. near Chicago, Ill., part of the long-time study program of concrete durability of the association. Concrete specimens in the field for seven years include slabs, beams, piers, pilings, and hollow boxes. Treatment of concrete surfaces for deicing has been part of the program. Twenty-seven cements, including all of the A.S.T.M. C 150 cements (five types) and both cements in A.S.T.M. Specification C 175 were used in combination with good and poor aggregates. Mix designs were varied to include rich, intermediate, and lean mixes. The water-cement ratio was varied to give very low

to very high slump in the concrete. There is general agreement among those who have seen this project that all cements when used in richer mixes approximating 6½ bags per cu. yd. with sound aggregate and mixed to render low slump, are showing excellent durability after seven years. The placement of these specimens was carefully controlled and sufficient time was allowed for the concrete to settle in the form—in some cases as much as one-half hour before the surface was struck or finished. These surfaces are withstanding weathering. It would seem from this that workmanship and placement are very important details.

Finally, I should like to leave this thought with you. Through the viligant efforts of A.S.T.M. Committee C-1, which is a representative cross-section of consumer interests, general interests, and manufacturers of cement, the construction industry is provided with highly specialized standards for portland cement. It is to your interest to learn more about them and use them.

Application of Synthetic Fibers, Including Glass, in the Textile Industry[1]

Rene Bouvet, American Viscose Corp.

THE LAST decade has witnessed the introduction in commercial channels of more true synthetic fibers than in any other like period of history. It has been exceedingly generous in its challenge to the textile world for new heights in achievement in the domain of their applications.

It is not likely that anyone could discuss and do justice to this imposing group of new fibers, including Fiberglas, in the time allowed, and it is fortunate that their textile applications have been set as boundary. On the other hand, intelligent usage demands thorough knowledge of fiber properties so that review of their outstanding characteristics is in order to support the logic of their applications.

The fibers briefly described are Fiberglas, Nylon, Vinyon, Saran, and Polyethylene.

FIBERGLAS

Barely over a half century ago, the first successful coarse glass fibers were drawn from the heated ends of glass rods by Edward D. Libbey of the Libbey Glass Co. Such glass fibers were exhibited at the Columbian Exposition in the form of lamp shades. While the interest in this type of fiber remained keen, nothing constructive took place until 1931 when two leaders in the glass field instituted an intensive research program to develop the production of glass fiber in a commercially usable form. From that time on, considerable advances were made, and fine filaments pliable enough to be braided or woven became a reality within a few years. In 1938, the Owens-Corning Fiberglas Corp. was formed to continue the manufacturing of glass fibers, to carry on further research, and to apply Fiberglas according to its particular properties.

Fiberglas spinning is fascinating, especially with respect to the speed at which such seemingly fragile filaments are drawn. The filaments are drawn at the incredible speed of two miles per minute from ⅝ in. glass marbles brought to the melting point in electric furnaces. The yarn is twisted in the single and then generally plied, for very few fabric constructions call for the use of single ends.

Continuous filament Fiberglas yarns offered under the No. 900-$\frac{1}{0}$ size are 51 deniers and carry 102 filaments so that each filament sizes 0.5 denier. The diameter of such filament is 0.00028 in. or about 6 microns. With the exception of Polyfiber, there is no other commercial fiber of equal fineness in existence. Moreover, the 0.00028-in. filament is relatively coarse in Fiberglas parlance, for the type known as superfine, available in the staple fiber form, has a diameter of 0.00002 in. or ½ micron. In fact, it is so fine that it may barely be detected with the naked eye.

Fiberglas has a specific gravity of 2.54 and is heavier than any other textile fiber. It offers a remarkable tensile strength (6½ g. per denier dry, and 6 g. per denier wet). Being waterproof and having no stretch, it possesses the *par excellence* dimensional stability. It is noninflammable and remains unaffected by heat up to 750 F. at which point it begins to shrink slightly (0.3 per cent). Its softening point is 1000 F. It resists most acids even in their concentrated forms, is immune to bacteria, and does not retain odors. Fiberglas offers good resistance to abrasion by materials other than glass, but glass cuts it surprisingly fast. Flexing will damage it, particularly in the wet state.

For efficient weaving, certain conditions must be met, and it is generally conceded that adequate warping constitutes the keystone of successful subsequent operations. It is essential that uniform tension be maintained in warping. The reason for this is that the length of Fiberglas is final, for since the yarn has neither the ability to shrink nor to yield, any difference in length within the warp causes either slackness or tightness, both of which are exceedingly troublesome. Fiberglas is generally warped from cones onto a horizontal warper. Accurate adjustment of the elevators supporting the first warping section is essential.

The loop strength of Fiberglas is low, thereby precluding the tieing of knots. Weavers therefore revert to spare ends or to the use of methyl methacrylate when any piecing is to be done.

The fiber characteristics mentioned, namely, strength, permanency, and immunity from the attack of various elements constitute the basis for the many textile applications in which Fiberglas has become best known.

An all-glass fabric which has set high performance standards is the 0.015 in. cloth being used for electrical insulation. This cloth has truly revolutionized the electric motor industry. Its strength (tensile and tear) combined with a small space factor and high heat resistance, has made it possible to reduce the motor weight in proportion to its power and to decrease measurably the maintenance costs. A varied line of woven glass fabrics, running from light to heavy, finds its way as reinforcement for laminates, coated fabrics, window shades, seat covers, awnings, canopies, golf bags, etc. Being noninflammable, Fiberglas serves safely and lastingly as curtains, draperies, lamp shades, cinema screen, and a host of other articles demanding permanency and safety.

While it is conceded that Fiberglas is not practical in clothing to be worn close to the body, it is well suited for the decorative field in the form of ribbons, millinery, costume ornaments, etc. Moreover, its applications in the medical and surgical lines already are being compiled into a long and interesting list, among them being the Fiberglas plastic bandage, a knitted fabric made of Fiberglas and acetate, replacing in its functions casts made of plaster of Paris.

[1] Condensed version of a talk presented at the Philadelphia District—Committee D-13 Meeting in Philadelphia on October 16, 1947.

A relatively new and very interesting knittable and weavable yarn is the one known as "Tensolite." It is made of a Fiberglas core covered with vinyl resin. In addition to strength, "Tensolite" offers excellent flexing and high abrasion resistance.

The versatility of Fiberglas has been further enlarged by the possibility of dyeing it. For over a year, continuous filament yarns have been spun with a suitable coating of the gelatin type which permits package dyeing in a manner similar to that followed for rayon. Acid colors yield a dyed yarn fast to light and dry cleaning, but not wash resistant. Vat colors are being developed and may become available in the not too distant future.

Staple fiber produced by blast drawing of the molten glass into fibers is not as readily adaptable to textile application as continuous filaments. Morever, it plays an important rôle in industrial fields where its thermal stability, power of insulation from heat or cold, and acoustic control properties are used to advantage. The insulating power of superfine staple fiber has proved to be so effective that its incorporation in outer garments for cold climates has proceeded much beyond the experimental stage. Spun staple fiber fabrics are being currently produced as well as yarns combining staple fibers and asbestos.

Nylon

Among the successful true synthetic fibers of our age, nylon stands out. In many respects, it is unique. While popularly described as being made from "coal, air, and water," the more precise definition given by E. I. du Pont de Nemours is "a generic term for any long chain synthetic polymeric amide which has recurring amide groups as an integral part of the main polymer chain, and which is capable of being formed into a filament in which the structural elements are oriented in the direction of the axis." This definition covers a vast group of related products or materials capable of serving a broad range of textile applications.

Commercial production of nylon began as late as 1937. It gained immediate and wide public acceptance. Its production has been increasing ever since at a fast rate, but in spite of that it falls short of keeping up with an evergrowing demand.

No effort will be made here to mention all its many interesting and varied physical properties, but some of the salient ones are noted. The great tensile strength possessed by this fiber, ranging from 4.5 to 8 g. per denier, according to the type, makes it desirable for end uses requiring either lightness or strength or both combined. Its wet tenacity being equal to 85 per cent of its dry, it lends itself admirably to rainwear, tenting, and the like. The faculty it possesses to check the moisture regain to about 4 per cent at 65 relative humidity and to absorb less than 7 per cent of water when immersed, lends to nylon fabric the ability to dry quickly. In comparison with most other fibers, it has a low specific gravity (1.14) and a surprising abrasion resistance.

Conventional textile machines of the braiding, knitting, and weaving trades are readily adaptable to its processing.

Very large quantities of continuous filament nylon have been consumed in the knitting industry, and the reputation it has acquired in the hosiery field need not be further stressed. The yarn knits well, provided it receives the pre-treatment recommended for it.

It withstands the weaving strain when twisted with a fair number of turns or when warps made of single end sized yarn are topped with an additional size applied in an additional slashing operation. Slashing of a nonpresized nylon warp still constitutes a problem which is hoped to be largely reduced with the aid of a new size recently introduced by du Pont and known as PMA (polymethylacrylate acid).

The ease with which this fiber can be stretched demands that it be handled with well-controlled tension. In fact, nylon stretches under lesser loads than cotton, wool, or rayon will normally bear, and the difference is so marked that it is advisable to give to the requirement of low and uniform tension, constant attention during the manufacturing process. The technical data on the correct method of handling nylon is so perfected that any textile plant willing to follow a set of well-defined rules faces no more than an average manufacturing task.

Prior to the recent World War, nylon remained largely in the hosiery field. During the war years, nylon served the exacting requirements of the military needs. Its great strength, lightness, resistance to water and to many chemicals, mildew, insects, etc., answered better than any other fiber could the properties demanded in parachutes, straps, safety belts, insect screen, hammocks, clothing, and even shoe laces for tropical climates; also, tire cord fabrics for heavy cargo planes. Its elasticity and slow recovery were exploited in the famous aerial pickup tow rope. The monofilament nylon invaded many speciality fields such as toothbrushes, paint brushes, screening, and tennis racquet strings.

Since the output of nylon was released to the civilian needs, its textile applications have expanded greatly although still hampered by the limited yarn production. It is now most successfully used in durable lightweight clothing, dress goods, quick drying underwear garments, indestructible marquisette curtains, rugged sailcloth, hardwearing upholstery, laces, umbrella cloth, bolting cloth, household furnishings, noncrushing transparent velvet, and a host of others.

Intimate blends combining nylon staple with other fibers such as rayon, wool, etc., hold interesting promises as to strength, abrasion resistance, durability, and will no doubt be exploited as soon as nylon staple becomes available on a commercial basis

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To the A.S.T.M. Committee on Membership

1916 Race St., Philadelphia 3, Pa.

Gentlemen:

Please send me information on membership in A.S.T.M. and include a membership application blank

(Signed)_____

Address_____

Date_____

Vinyon

In 1939 a synthetic fiber, dry spun from a copolymer of vinyl chloride and vinyl acetate was made available in a limited amount by the American Viscose Corp. (Vinyon was first developed and spun by Union Carbide and Carbon in 1937.) Upon varying the proportions of the two vinyls, it was found that the fiber characteristics could be changed within a certain range, and of the various types thus developed, two remain available today—Vinyon-HH (unstretched) and Vinyon-CF (stretched).

Freshly spun yarn (unstretched) is wanting in strength— 1 g. per denier, and its extensibility is very high. However, through stretching and the resultant orientation of the molecules along the filament axis, a high tensile strength is reached—4 g. per denier. Being water repellent, the fiber strength and extensibility remain unaffected even after complete immersion in water. By the same token, Vinyon remains subject to static. Its resistance to acids and alkali is notable and valuable in its applications. It does not support combustion, but the limit of its thermal stability is reached at about 150 F. In late Vinyon, the thermal stability has been raised to over 212 F.

An interesting feature of this material is that its textile behavior is identical to that of natural fibers so that it can be processed on nearly any existing machine without change. Moreover, the handle of fabrics made of it comes singularly close to that of natural fiber, silk in particular.

When processing it, one must avoid the use of procelain guides. Vinyon by nature is allergic to it, particularly while in the low twist state, and metal guides are recommended. To combat static, neutralizers or high humidity is recommended. The latter can be resorted to freely, for it is possible to run Vinyon in the wet state under reasonable tension without injuring it. Vinyon is being warp sized, limiting the maximum temperature applied at slashing time according to the thermal stability of the type being processed. Dyeing of the fiber still offers difficulties. They are being gradually overcome by improved dyeing methods and by the development of new type Vinyons having higher thermal stability.

The present textile applications of Vinyon are largely predicated on its resistance to chemicals, to water, its strength and thermal properties.

Knitted Vinyon work shirts, smocks made of woven fabrics are found invaluable by operators in chemical plants and laboratories. They save the regular clothing, also protect the operators.

Vinyon is also used as filter fabric and in screen printing cloth, for in addition to long life, the screen printing cloth offers superior registration and unexcelled stability.

Another distinctive property of Vinyon is being exploited in lightweight embroidery fabrics which have completely replaced silk in that field. The solubility of Vinyon in acetone renders this application unusually simple and practical.

An awning made of a tightly woven Vinyon duck not only offers ideal protection, but greater life, for such an awning can be folded, also stored away with greater immunity than those made water repellent by the aid of a brittle surface coating.

Automobile window channel pile fabrics made of Vinyon are extremely durable, and the nonswelling property of the fiber promises to ban jammed windows from the cars of tomorrow.

For some time past, Vinyon has served the shoe and bag industries in the form of a heavy net, either woven or knitted. To circumvent the dyeing difficulties experienced in the past, dope dyed yarn is now being used.

Admittedly, Vinyon is not suitable for garments likely to be pressed or ironed because of its low thermal stability; however, it has very desirable attributes for millinery ornaments, garment accessories, bathing suits, rainwear, umbrella cloth, etc. The point of thermal stability can be exploited to obtain novel effects—matelasse, cloque, seersucker, etc.

The application of Vinyon extends to a few nontextile lines such as bristles, surgical sutures, ropes, and heat sealing media. Vinyon staple serves as pump packing; it is added to the composition of felt to improve the water repellency and stability, and of tea bag paper to increase the strength.

Vinyon-N, a new and better type of thermoplastic fiber stemming out of a copolymer of vinylchloride and acrylonitrile, is being developed. All the desirable properties of the previously cited Vinyons are retained while a greater thermal stability has been achieved.

Saran-Velon-Permalon

The synthetic fibers indentified with any of the above names represent a comparatively new yarn extruded from vinyiidene chloride—a resin manufactured by the Dow Chemical Co. The development of this resin dates back about ten years. Yarns were offered to the trade in 1939, and three organizations—The National Plastics Products Co., Firestone Rubber Co., and The Visking Corporation—are extruding it.

The general properties of this synthetic fiber, of which the specific gravity is 1.72, are excellent resistance to water, to chemicals at ordinary temperature, and good dimensional stability up to 170 F. Its dry tensile strength of 1.8 g. per denier and dry extensibility of 30 per cent remain unchanged in the wet state. It does not support combustion, offers high abrasion resistance, and resists soiling to an unusual extent.

The bulk of the yarn so far produced has been of the monofilament type ranging from 0.012 to 0.008 in. in diameter. Manufacturing preference has been given

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To the A.S.T.M. Committee on Membership, 1916 Race St. Philadelphia 3, Pa.

Gentlemen:

Please send information on membership to the company or individual indicated below.

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_____

This company (or individual) is interested in the following subjects: *{indicate field of activity, that is, petroleum, steel, non-ferrous, etc., etc.}*

_____

*{Signed}*_____

Date_____ **Address**_____

to the 0.012 in. size of which the equivalent size in denier is 1150.

Such monofilament yarns are well adaptable to braiding, knitting, and weaving, and the problems they present in textile processing stem largely from their coarseness and weight. The large size and consequently heavy weight of the packages on which they must be placed to assure efficiency of operation, the unusual weight of the fabrics in which they are used, everything demands the aid of adequate engineering to answer the bulk and weight problem.

Sturdy looms capable of weaving wide goods weighing as much as 1½ lb. per linear yd., well furred shuttles, and large shuttle bobbins are some of the well-known requirements.

The most successful applications of Saran, Velon, and Permalon have been in connection with seat covers, curtains, insect screen, handbags, awnings, and tablecloths—all of which are articles seldom exposed to high temperature but demanding durability, resistance to elements and to soiling.

Lately, multifilament yarns sizing 140 denier and comprising ten filaments have been developed. The tensile strength of this improved yarn has been increased to 2.5 g. per denier, the extensibility reduced to 22 per cent, and the fiber diameter is down to 0.001 in. Numerous difficulties still have to be overcome before such multifilament yarn becomes a commercial proposition. It has created a great deal of interest and justly so, for the experimental fabrics made with it are indeed most attractive. It is expected that a staple fiber will be made available in the not too distant future.

Polyethylene

Polyethylene is the polymerization product of ethylene under pressures ranging from 500 to 3000 atmospheres. The molecular weight of the resin increases according to the pressure used, and 3000 atmos pheres produces a polymer which is in the range used for fibers.

The Imperial Chemical Industries, Ltd., introduced the resin process in this country, and in 1944 E. I. du Pont de Nemours and the Bakelite Corp. took up the manufacturing of polyethylene.

The noncorrosive resin, in the form of small, wax-like particles, is melted and extruded under pressure at 432 F. as monofilament or multifilament yarns capable of being further drawn in the cold state to finer diameter of greater strength.

The National Plastics Products Co. is manufacturing yarns under the name of Wynene. The American Viscose Corp. is about to start production of yarns on a small scale.

Among the properties of this fiber, its low specific gravity of 0.92 stands out. Being waterproof, polyethylene floats. No other fiber compares with it as regards lightness, and this characteristic offers something quite unusual.

The dry strength ranges from 1.5 to 3.0 g. per denier. Higher tensile strength is within reach—however, at the expense of thermal stability. The flexibility of this product is excellent and lasting, for it contains no plasticizer as generally found in other resins. Its thermal stability ceases at 150 F. From that point on, it loses strength and shrinks about 3 per cent at 150 F., 5 per cent at 170 F.

Yarns being offered for the present are of the monofilament type with a diameter of 0.025 in. down to 0.012 in. They are coarse but reasonably light—in fact, the 0.012 in. size is about 600 deniers which, of course, is considerably less than the size of monofilament yarns of the same diameter made of other resins. This point is rather important, for it has a profound influence on the ultimate cost.

It is thought that the present cost can be appreciably reduced when manufactured on a larger scale.

Other Fibers

There are several other synthetic fibers which should be mentioned such as:

Fiber A—a promising, high-strength, high melting point but, for the moment, poor dyeing newcomer developed by du Pont and made of polymethacrylonitrile.

Terylene—a poly ester of terephthalic acid and ethylene glycol developed by the Imperial Chemical Industries, Ltd., of England and now being introduced in this country by E. I. du Pont de Nemours.

Polyfiber—made of polystyrene and developed by the Dow Chemical Co.

Also a group of synthetic protein fibers such as Ardil made of peanut protein and introduced in 1945 by the Imperial Chemical Industries, Ltd.; also, a soybean protein together with others less known.

Prospects

What are the prospects for the present and new synthetic fibers? This question can only be answered in a general way—that modern life, with its insatiable desire for new and better things, will provide room for them cannot be doubted, and the place they will occupy should grow in importance as they are perfected. Their future, however, depends largely on what they can do, on their properties, on their ability to meet increasingly exacting requirements and more refined taste. Of course, their price will remain an important, if not the controlling, factor. Moreover, reason dictates that there is a limit to the type of fibers which can be produced economically and capable of serving useful purposes.

It is my belief that textile technicians can do much to assure the early success of new additions to the textile family. To be sure, no fiber can be expected to be universal in its applications. The modern trend is toward greater variety—and this suggests that the outstanding properties of the new fibers be featured with gusto, while educated caution protects them from end uses for which they are unsuited.

ACI Meeting in Denver

The 1948 Annual Meeting of the American Concrete Institute is being held in Denver, Colo., February 23–26, inclusive. A number of interesting papers and reports are scheduled, and Bradley Dewey, former U. S. Rubber Director, will present the dinner address on Tuesday, February 24, giving the latest information on the results of the Bikini tests. Certain A.S.T.M. technical committees are meeting during the ACI sessions. Those interested in buffalo meat can participate in the special barbecue luncheon on February 24.

Prize Award for Work in Analytical Chemistry

Chester F. Fisher, President of the Fisher Scientific Co. and of Eimer and Amend, who recently received the Pittsburgh Award of the American Chemical Society, has established a new award to recognize and encourage outstanding contributions to analytical chemistry. The A. C. S. Board of Directors will administer the award, the first of which will probable be made at the A. C. S. fall meeting in September. It consists of a $1000 prize and an original etching. The Canvassing Committee which has been appointed includes C. M. Alter, chairman, M. G. Mellon, and G. E. F. Lundell.

A.A.A.S. to Have Centennial Celebration

The American Association for the Advancement of Science, plans to have a Centennial Celebration in Washington, D. C., September 13–17, inclusive. The keynote of the Centenary is to be "One World of Science." Numerous symposiums of interest to science and also to the general public will be held.

Because of the lack of meeting facilities the affiliated and associated societies of the A.A.A.S. will not have their annual meeting at this time, but some of the groups will meet before or after the Centenary. The A.S.T.M. has been interested in the work of this association, specifically Section M on Engineering, for many years. Many A.S.T.M. members are also affiliated with the A.A.A.S.

New Members to January 7, 1948

The following 70 members were elected from November 24, 1947, to January 7, 1948, making the total membership 6394.

Names are arranged alphabetically—company members first, then individuals.

Chicago District

AMERICAN HOSPITAL ASSN., George Bugbee, Executive Director, 18 E. Division St., Chicago 10, Ill.

HANDY, WALTER N., Sales Manager, Combustion By-Products, 228 N. LaSalle St., Chicago 1, Ill.

MAXON, GLENWAY, Consulting Engineer, 757 N. Water St., Milwaukee 2, Wis.

Cleveland District

DERHAMMER, C. R., Secretary, The Lakeside Steel Improvement Co., 5418 Lakeside Ave., Cleveland 14, Ohio.

WALTHORN, HENRY J., Chief Chemist, Carnegie-Illinois Steel Corp., Youngstown, Ohio.

Detroit District

HANNUM, JOHN ANDREW, President, Hefco Laboratories, 20120 Sherwood, Detroit 12, Mich.

New England District

GUMMED INDUSTRIES ASSN., INC., THE, F. W. Farrell, Technical Director, McLaurin-Jones Co., Brookfield, Mass.

CLEMENT, WILLIAM D., Instructor, Department of Mechanical Engineering, University of New Hampshire, Durham, N. H.

LEITCH, G. G., Chief Metallurgist, Fellows Gear Shaper Co., Springfield, Vt.

LUCE, STANFORD L., Secretary, Wool Associates of the New York Cotton Exchange, Inc., 10 High St., Boston, Mass.

SIEGFRIED, VICTOR, Chief Research Engineer, American Steel and Wire Co., 767 Millbury St., Worcester 7, Mass.

STERN, HERMAN LEE, Design and Development Engineer, General Electric Co., 100 Woodlawn Ave., Pittsfield Mass. For mail: Box 233, Pittsfield, Mass. [J]*

New York District

COONS, JOSEPH S., Ceramic Engineer, General Ceramics and Steatite Co., Keasbey, N. J. For mail: 344 Middlesex Ave., Metuchen, N. J. [J]

DEMITRACK, GEORGE, Graduate Student, Columbia University, New York, N. Y. For mail: 1773 Weeks Ave., Bronx 57, New York, N. Y. [J]

HALE, A. H., Plastics Dept., E. I. du Pont de Nemours and Co., Inc., Arlington, N. J.

HARRIS, HAROLD C., Metallurgist, Mack Manufacturing Corp., New Brunswick, N. J.

IRSA, ADOLPH PETER, Chemical Engineer, Hydrocarbon Research, Inc., New York Ave., Trenton, N. J. For mail: 39-06 Sixty-third St., Woodside, L. I., N. Y. [J]

SANDERS, PALMER W., Chief Chemist, Pequanoc Rubber Co., Butler, N. J.

SANTORO, W. E., Technical Director, Standard Varnish Works, 2600 Richmond Terrace, Staten Island, N. Y. For mail: 166 Jewett Ave., Jersey City 4, N. J.

SHOHET, NORMAN E., Textile Consultant, Bombay, India. For mail: 15 Park Row, New York 7, N. Y.

STANSCHECK, THOMAS BOURKE, Assistant in Layout and Scheduling, General Fibre Products Co., 53-01 Seventy-fourth St., Maspeth, New York, N. Y. For mail: 1442 E. Thirty-fifth St., Brooklyn 10, N. Y.

Northern California District

GOODALE, R. W., Manager, Lubricant Div., Marketing Dept., Standard Oil Co. of California, Box 3495, San Francisco 20, Calif.

Philadelphia District

AJAX ENGINEERING CORP., Manuel Tama, Vice-President, Box 1418, Trenton, N. J.

CARBON MALLEABLE CASTING CO., INC., Charles P. Speitel, President and Treasurer. 712 S. Prince St., Lancaster, Pa.

CURTIS, BENJAMIN TALMADGE, Student Engineer, United Engineers and Constructors, Inc., 1401 Arch St., Philadelphia, Pa. For mail: 432 S. Forty-second St., Philadelphia 4, Pa. [J]

KUDRAVETZ, BORIS SAWA, Junior Engineer, Westinghouse Electric Corp., Aviation Gas Turbine Division, Lester, Pa. For mail: 5019 Chester Ave., Philadelphia 43, Pa. [J]

RICHARDS, JOHN T., Sales Engineer, The Beryllium Corp., Reading, Pa. For mail: 1324 Perkiomen Ave., Reading, Pa.

SEIDEL, LEON, Textile Engineer, Frank Associates, Cementon, Pa.

THORN, WILLIAM J., Philadelphia Branch Manager, Innis, Speiden and Co., 401 N. Broad St., Philadelphia 8, Pa.

Pittsburgh District

SHERWIN, LEE A., Chief Chemist, Rochester & Pittsburgh Coal Co., Indiana, Pa. For mail: 1218 Philadelphia St., Indiana, Pa.

St. Louis District

PARKS COLLEGE OF AERONAUTICAL TECHNOLOGY, ST. LOUIS UNIVERSITY, James F. Reagan, Head of Aeronautical Engineering Dept., Parks Airport, East St. Louis, Ill.

WEBER, ADOLPH CARL, Director of Research and Sales Engineering, Laclede Steel Co., 1317 Arcade Bldg., St. Louis 1, Mo.

Southern California District

BREUER, ROLF O., Materials Engineer, U. S. Navy, Terminal Island Naval Shipyard, Terminal Island, San Pedro, Calif. For mail: 24 Annandale Rd., Pasadena 2, Calif.

POLLAK, JAMES E., Manager, Construction Materials, Southwest Steel Rolling Mills, Box 3518, Terminal Annex, Los Angeles 54, Calif.

Washington (D. C.) District
(In Course of Organization)

MOCK, JUDSON, VOEHRINGER CO. OF NORTH CAROLINA, INC., Edward K. Atkinson, Purchasing Agent, Box Q-1, Greensboro, N. C.

WEST VIRGINIA STEEL AND MANUFACTURING CO., W. G. Summer, Executive Vice-President, Box 118, Huntington 6, W. Va.

DE LOLLIS, NICHOLAS J., Organic Chemist, National Bureau of Standards, Connecticut Ave. and Van Ness St., Washington, D. C. For mail: 1923 Biltmore St., N. W., Washington 9, D. C.

INSLEY, HERBERT, Chief, Division of Mineral Products, National Bureau of Standards, Washington 25, D. C.

ROSING, BORGE, Vice-President and General Sales Manager, West Virginia Steel and Manufacturing Co., Box 118, Huntington 6, W. Va.

Western New York and Ontario District

AULCRAFT PAINTS, LTD., W. H. Short, Factory Manager, 313 Symington Ave., Toronto 9, Ont., Canada.

U. S. and Possessions

ASSOCIATED LABORATORIES, Malcolm L. Playfair, Chief Chemist, 2419 S. E. Powell Blvd., Portalnd 2, Ore.

AYRSHIRE COLLIERIES CORP., J. J. Merle, Chief Chemist, Box 8, Staunton, Ind.

COMMERCIAL SOLVENTS CORP., Jerome Martin, Director of Research, Research Dept., 1331 S. First St., Terre Haute, Ind.

GREGG, CHARLES L., Chemist, The Dow Chemical Co., Midland, Mich. For mail: 408 Townsend St., Midland, Mich.

GUILLAUME, ROBERT O., Co-owner, Northern Kentucky Medical Laboratory, Doctors' Bldg., Seventh and Scott Sts., Covington, Ky. [J]

HEMPHILL, ADLEY WALTON, Graduate Student, Purdue University, West Lafayette, Ind. For mail: 1133 N. Thirteenth St., Lafayette, Ind. [J]

HILL, J. E., Metallurgical Engineer, Tennessee Coal, Iron and Railroad Co., Birmingham 2, Ala.

JACOBS, KEITH S., Chemical Engineer, Ironsides Co., 270 W. Mound St., Columbus 16, Ohio. [J]

LARSON, LEWIS P., Paint Chemist, American Zinc Sales Co., Box 327, Columbus 16, Ohio.

MCRIGHT, RALPH B., Adjunct Professor, Engineering Dept., University of South Carolina, Columbia, S. C.

MERRIAM, E. S., College Professor, Marietta College, 231 Fourth St., Marietta, Ohio.

SMITH, JOAN, MRS., Textile Technician, Fashion Frocks, Inc., 3301 Colerain Ave., Cincinnati 25, Ohio. [J]

WILLIAMS, THOMAS F., Engineer of Construction, U. S. War Dept., Huntington, W. Va., District, Huntington, W. Va. For mail: Box 507, Paintsville, Ky.

YAVNER, EARL M., Maintenance Engineer, Hechalutz Farm, R.F.D. 2, Wappingers Falls, N. Y. [J]

YOUNGQUIST, W. G., Engineer, U. S. Forest Products Laboratory, Madison 5, Wis.

ZEIGLER, SAMEUL J., Resident Chief Engineer, Solar Aircraft Co., Des Moines, Iowa.

Other than U. S. Possessions

ARTIFICAL SILK CO., LTD. "ETMA," Agias, Annis St., Athens, Greece.

BRITISH SHIPBUILDING RESEARCH ASSN., THE, E. Ower, Intelligence Officer, 5 Chesterfield Gardens, Curzon St., London W.1, England.

CIA. DE INDUSTRIAS Y AZUCAR S. A. (COIA), Luis Moro A, Manager, Casilla 14-D, Santiago, Chile.

DYNA, REVISTA DE LA A.N.I.I., Navarra 1, 1º, Bilbao, Spain.

CHANG, JIMMY C. H., Director, Chief Chemist and Factory Manager, The Great China Finance and Development Corp., Ltd., 109 National Bank Bldg., Hongkong, China. For mail: 23 Fung Fai Terrace, First Floor, Happy Valley, Hongkong, China.

DORLAND, RODGER M., Director of Research, Abitibi Power and Paper Co., Ltd., Sault Ste. Marie, Ont., Canada.

FREUDENTHAL, ALFRED M., 25 Khen Blvd., Tel Aviv, Palestine. Visiting Professor, University of Illinois, Talbot Laboratory, Urbana, Ill.

GAYNOR, JOHN S., Manager, Anglo Egyptian Oilfields, Ltd., Shell House, Cairo M. E., Egypt.

LAZAR, OSCAR, Principal, McLachlan & Lazar, Uranium House, Booysens Rd., Johannesburg, South Africa. For mail: Box 3344, Johannesburg, South Africa.

LEUNG, MICHAEL S. K., Chemist in Charge, Liu Ho Kou Iron Works, Ltd., 1 Bailey St., Ma Tau Wei Rd., Kowloon, Hongkong, China. For mail: 23 Fungi Fai Terrance, First Floor, Happy Valley, Hongkong, China. [J]

LOPEZ, MANUEL GARZA, Head of Inspection Dept., Cia. Fundidora de Fierro y Acero de Monterrey, S. A., Apartado Postal 206, Monterrey, N. L., Mexico.

SISSENER, T., Metallurgical Engineer, Myrens Verksted, Oslo, Norway.

STAROSTA, O., Assistant Technical Manager, Tana-Foundry, Zbrojouka Brno, n. p., Týnec Nad Sazavou, Czechoslovakia. For mail: c. p. 10, Týnec Nad Sazavou, Czechoslovakia.

TALISA E, LUIS, Chemical Engineer, Casilla 579, Lima, Peru. [J]

* [J] denotes Junior Member.

Personals . . .

. . . News items concerning the activities of our members will be welcomed for inclusion in this column.

CHESTER G. FISHER, President and founder of the Fisher Scientific Co., Pittsburgh, and a member of A.S.T.M. for many years, received the Pittsburgh Award at the December meeting of the American Chemical Society. This was given Mr. Fisher for "outstanding service to chemisty." He has been a member of the A.C.S. since 1903 and has taken very active interest in many problems in this field. One of his interesting hobbies is the discovery and perpetuation of alchemical-historical works of art.

FRED M. ZEDER, Vice-Chairman of the Board, Chrysler Corp., has been elected to the Board of Directors of the Detroit Trust Co.

FREDERICK G. WEED, former Director of Research, is now President of the Rinshed-Mason Co., Detroit. Mr. Weed is serving as chairman of the 1948 A.S.T.M. Photographic Committee, which will sponsor a display and competition during the annual meeting in Detroit, June 21 to 25, inclusive.

R. G. McELWEE, Manager, Foundry Alloy Div., Vanadium Corp. of America, Detroit, has been named to receive the American Foundrymen's Association John A. Penton medal for "outstanding contributions to the dissemination of information to the Foundry Industry, especially, for his splendid efforts on behalf of the Cupola Research Project." PETER E. RENTSCHLER, President, The Hamilton (Ohio) Foundry & Machine Co., will receive the AFA Peter L. Simpson medal for his "outstanding work in promoting better housekeeping and safety practices in the foundry and for the inspiration he has given the Foundry Industry in the field of public relations." These awards will be presented at the annual banquet of the AFA in Philadelphia, May 7. At the same time, honorary membership will be conferred upon the retiring international President MAX KUNIANSKY, General Manager, Lynchburg (Va.) Foundry Co.

FRANS V. E. VAURIO has accepted appointment as Development Chemist, Milprint, Inc., Milwaukee, Wis. He was previously Research Asst., The Institute of Paper chemistry, Appleton, Wis.

RAYMOND J. FRANKLIN, formerly Manager, The Chicago Hardware Foundry Co., North Chicago, Ill., is now President, Cirod Corp., Lyons, Ill.

HUBERT CHARLES RUZICKA is now Chemical Engineer, Rumford Chemical Works, Rumford, R. I. He was formerly associated in a similar capacity with the American Cyanamid Co., Stamford, Conn.

DEAN E. SHULL, Jr., former Ensign, U.S.N.R., has accepted appointment as Engineer, with Hajoca Corp., Chattanooga, Tenn.

WILLIAM B. WALLIS, President, Pittsburgh Lectromelt Furnace Corp., has been nominated for President of the American Foundrymen's Association in 1948–1949, and EDWIN W. HORLEBEIN, President, Gibson & Kirk Co., Baltimore, is the nominating group selection for Vice-President. Both Mr. Wallis and Mr. Horlebein have been members of A.S.T.M. for many years, and Mr. Wallis has been a member of Committee A-3 on Cast Iron since 1931. ANDREW M. FULTON, Vice-President of Northern Malleable Iron Co., St. Paul, Minn., also a member of A.S.T.M. for many years, has been named for a three-year directorship. And VICTOR E. ZANG, Vice-President of Unitcast Corp., Toledo, Ohio, also is named for a directorship.

WILLIAM B. PRICE has retired as Director of Research from Scovill Manufacturing Co., Waterbury, Conn., being succeeded in this capacity by F. M. Barry. Mr. Price has been affiliated with A.S.T.M. since 1913, and has been active in the work of various technical committees.

GÖRAN PHILIPSON, formerly Chemical Engineer, Centralbolaget for Kemiska Industrier, Stockholm, Sweden, is now associated with A. B. Svenska Metallverken, Upl'ands-Vasby, Sweden.

M. A. TEIXEIRA DE CASTRO has accepted an appointment as Technical Director, Companhia de Cimento Portland Paraiso, São Paulo, Brazil. He was previously associated as Superintendent with Cia. Brasileira de Cimento Portland Perus in São Paulo.

WILLIAM MUIR ROBB, formerly Field Engineer, Ayeling-Barford, Ltd., Grantham, Lincs., England, is now affiliated with W. M. Robb, Ltd., West Drayton, Middlesex, England.

G. FORREST is now with the Aluminium Labs., Ltd., Banbury, Oxon, England. He was formerly with the Northern Aluminum Co. of England.

JUD A. GUSTIN, who had been associated with the Bessemer Limestone and Cement Co., Bessemer, Pa., as Assistant General Superintendent, is now Mill Superintendent, with R. T. Vanderbilt Co., Inc., Gouverneur, N. Y.

GEORGE ENGELLAND, formerly Chief Chemist, The National Refining Co., Findlay, Ohio, is now affiliated with the White Eagle Div., Socony-Vacuum Oil Co., Inc., Augusta, Kans.

WILLIAM P. PUTNAM, a long-time member of A.S.T.M., is retiring from his activities with the Detroit Testing Laboratory which he established many years ago. This laboratory has been purchased by a new group in the Detroit area. Mr. Putnam has been quite active in various phases of A.S.T.M. work, notably in Committee A-7 on Malleable-Iron Castings, and he has taken a genuine interest in the work of the Detroit District Council, of which he is a member.

WALTER BOHNSTENGEL, Engineer of Tests, the Atchison, Topeka & Santa Fe Railway, Topeka, Kans., for the past 35 years, and widely known to many A.S.T.M. members not only for his activities with the Santa Fe but also for his interesting hobby of weather forecasting, has retired from active duties. In A.S.T.M. he was particularly interested in the work of Committee A-1 on Steel but also was active in other technical groups. Mr. Bohnstengel, whose A.S.T.M. membership dates from 1914, is being succeeded as Engineer of Tests in the Santa Fe by E. B. Fields.

HERVEY S. VASSAR, since 1911 Laboratory Engineer of Public Service Electric and Gas Co., Maplewood, N. J., and a Past-President and Honorary Member of the Society, has retired from active work with his company. In recognition of his long-time work and as a tribute to him a dinner was held on December 11, at which a large number of his associates and friends were present. Included among the speakers at the dinner were A.S.T.M. Past-President F. M. Farmer and Executive Secretary C. L. Warwick. Mr. Vassar has a long and notable record of service not only in his industry but in many technical activities. He was President of A.S.T.M. in 1935–1936, and was an officer of several technical committees. He rendered notable service as chairman of the Administrative Committee on Standards and of the Special Study Committee. A rather detailed résumé of his work appeared in the August, 1947, BULLETIN which announced his election as an A.S.T.M. Honorary Member. Mr. Vassar plans to continue his interests in a number of activities.

HARRY J. LOVE, has retired as Managing Director of the National Slag Association. Announcement was made at the Annual Banquet of the Association on November 19, at which time a silver loving cup was presented to Mr. Love as a token of esteem from the Board members. Mr. Love has served the National Slag Association for over thirty years in the capacity of managing director, and, in fact, was largely responsible in organizing the association. He has been a member of the Society since 1917 and active in the work of Committee C-9 on Concrete and Concrete Aggregates, as a member of the Executive Subcommittee, and of Committee D-4 on Road and Paving Materials. Mr. Love is retained in a consulting capacity by the Association and will use that business address. He is being succeeded as Managing Director of the N.S.A. by E. W. Bauman, who is serving on several A.S.T.M. Technical Committees.

D. J. McADAM recently retired as Chief of the Thermal Metallurgy Section of the National Bureau of Standards, Washington, D. C. A member of A.S.T.M. since 1918, Mr. McAdam has rendered notable service on various technical committees and has contributed a number of outstanding technical papers, many of which have appeared in the *Proceedings*.

W. E. DAY, formerly Chief Metallurgist and General Foundry Supt., is now Director of Research, Mack Trucks Inc., Plainfield, N. J.

ANDREW VAN ECHO has joined the Wm. E. Pratt Mfg. Co., Joliet, Ill., as Metallurgical Engineer. He was formerly Chief Inspector for Joslyn Manufacturing and Supply Co., Ft. Wayne, Ind.

JOHN A. DEITRICH has been promoted from Metallurgical Engineer to Manager of the Alloy Tube Div., Carpenter Steel Co., Kenilworth, N. J.

CLARENCE W. BALKE, Emeritus Director of Research of the Fansteel Metallurgical Corp., North Chicago, Ill., is recipient of the 1948 Perkin Medal of the American Section of the Society of Chemical Industry. Dr. Balke's pioneer work in the rare metals resulted in major contributions to American industry and medicine.

ALBERT J. PHILLIPS, Superintendent, Research Dept., American Smelting and Refining Co. has been elected a Director of the American Institute of Mining and Metallurgical Engineers.

CHARLES HAYDOCK, Consulting Engineer, Philadelphia, Pa., has been appointed by Governor James H. Duff as a member of the Pennsylvania State Registration Board for Professional Engineers.

WILLIAM H. KLEIN, long-time A.S.T.M. member, has been appointed Operating Manager of the Lawrence Portland Cement Co., New York City, with headquarters at Northampton, Pa. For many years he has served as Assistant to the President, at the Easton branch of the company.

CARL A. MENZEL has been appointed Manager of the Housing and Cement Products Bureau, Portland Cement Association, Chicago. He had been affiliated with the Association for many years as Research Engineer. In his present capacity Mr. Menzel succeeds JOHN A. RUHLING who is now in charge of technical personnel training in the fundamentals of concrete making and concrete construction practices. Messrs. Menzel and Ruhling are both active in A.S.T.M. matters: Mr. Menzel has been affiliated as a member since 1934, is a member of the Chicago District Council, and of several technical committees; and Mr. Ruhling is a member of the masonry Building Unit committees.

ROBERT P. HARVEY, formerly Chief Chemist, Commercial Laboratories, Ltd., Ottawa, Canada, is now affiliated as Chemist with the Arvida Works Laboratory, Aluminum Company of Canada, Ltd., at Arvida, Province of Quebec.

AUBREY E. FORD is now Chief Chemist, Red Ash Eagle Coal Corp., Williamson, W. Va. He was previously associated with the Green Bag Cement Co. of West Virginia.

Industrial Research Institute, Inc., New York City, is awarding its 1948 medal to GAMES SLAYTER, Vice-President in Charge of Research and Development, Owens-Corning Fiberglas Corp., for his leadership in the development of glass fibers and their commercial application.

E. C. HOENICKE, Assistant to General Manager, Foundry Division, Eaton Mfg. Co., Detroit, and RALPH J. TEETOR, President of Cadillac Malleable Iron Co., Cadillac, Mich., were elected to the Administrative Council of the National Founders Association.

T. H. ADAIR has been promoted to Chief Plant Metallurgist of Atlas Steels Ltd., Welland, Ont., Canada.

OLIVER SMALLEY, President, Meehanite Metal Corp., New Rochelle, N. Y., has been appointed to the Advisory Council for Science and Engineering, University of Notre Dame.

WENDELL F. HESS, Associate Professor in Metallurgical Engineering and Head of Welding Laboratory, Rensselaer Polytechnic Institute, Troy, N. Y., is one of the four scientists awarded the $300 first prize for the best paper from a university source in the 1947 Resistance Welder Manufacturer's Association contest. Announcement of the award was recently made by the American Welding Society.

L. R. JACKSON, Research Supervisor, Battelle Memorial Institute, and Horace J. Grover, also of the Institute, are recipients of the award for the third best paper from an industrial source in the Resistance Welder Manufacturers' Association prize contest of the American Welding Society. Their paper was entitled "Fatigue Tests on Some Spot-Welded Joints in Aluminum-Alloy Sheet Material."

LESTER W. STROCK announces that in keeping with the increased scope of its activities the name of the consulting laboratories of which he is Vice-President and Director of Research, has been changed from Spectrographic Services and Supplies, Inc., to Saratoga Laboratories, Inc. The business of this organization now includes not only metallurgical, geological, geochemical and ore dressing research and developmental work, but has expanded into the field of general chemical, chemical engineering, and soil studies for the agricultural industries.

The BRITISH INSTITUTE OF PETROLEUM, London, announces that E. A. Evans has been nominated as President Designate of the Institute for the Session 1948–1949. Mr. Evans, who has been Chief Chemist to the Wakefield Group of Companies since 1915, is well known in the field of lubrication. He has been active for some years in the Motor Industry Research Association and is its present Chairman. In 1942–1943 he was awarded the Crompton Medal of the I. A. E. for his paper on "Extreme-Pressure Lubrication."

News of Instrument Companies and Laboratories

Ownership of the Detroit Testing Laboratory, a very active organization in the Detroit area, founded by W. P. Putnam in 1903, has been transferred by Mr. Putnam to a group headed by Douglas Dow, Jr., Formerly Director of Commercial Research of the Detroit Edison Co., Mr. Dow plans to expand the laboratory's activities. The Detroit Testing Laboratory has a long history of contributions to industry in the Detroit area, having served many of the automotive concerns and other leading companies there.

ARTHUR S. LAPINE & Co., 121 W. Hubbard St., Chicago, Ill., a chemical and laboratory supply firm, has leased 15,000 square feet in the 400 North Rush Street Building. This is in addition to their present quarters and will be known as Plant No. 3. Their chemical and physical laboratories will be expanded and will be in charge of Dr. Craig Johnson, formerly of the General Chemical Co. The new building will also contain manufacturing and warehousing operations.

Society Appointments

Announcement is made of the following appointments:

M. N. CLAIR, The Thompson & Lichtner Co., Inc., as representative, and R. E. HESS, A.S.T.M., as alternate, on the ASA Building Code Correlating Committee. (Reappointment)

MYRON PARK DAVIS, Otis Elevator Co., as representative and R. E. HESS, A.S.T.M., as alternate, on the ASA Safety Code Correlating Committee. (Reappointment)

H. J. BALL, Lowell Textile Institute, on ASA Sectional Committee L14 on Textile Test Methods, to succeed J. R. BONNAR, General Dyestuff Corp.

R. W. CRUM, Highway Research Board, on the American Documentation Institute for a term of three years, beginning January 1, 1948. (Reappointment)

E. J. KILCAWLEY, Rensselaer Polytechnic Institute, and F. J. CONVERSE, California Institute of Technology, as A.S.T.M. representatives at the International Soils Conference to be held in Holland, June, 1948.

H. J. GILKEY, Iowa State College, *Chairman;* H. W. GILLETT, Battelle Memorial Institute; and H. E. SMITH, Materials Engineer, White Plains, N. Y. on the Charles B. Dudley Medal Committee.

M. F. SAYRE, Union College, on the Committee on Richard L. Templin Award. (L. W. TELLER, Public Roads Administration, Federal Works Agency, and R. E. PETERSON, Westinghouse Electric Corp., continue as members.)

W. H. FINKELDEY, Singmaster & Breyer, *Chairman;* C. D. HOCKER, Union College; and L. W. HOPKINS, American Chain and Cable Co., Inc., on the Committee on Sam Tour Award.

W. C. GRANVILLE, Container Corporation of America, as Vice-Chairman of A.S.T.M. delegates on the Inter-Society Color Council.

NECROLOGY

DENNIS A. CROWLEY, Chief Metallurgist, Carnegie-Illinois Steel Corp., Pittsburgh, Pa. (November 16, 1947). Member since 1940.

J. HERBERT WALKER, a Vice-President of the Detroit Edison Co., and for many years active in A.S.T.M. work (December 1, 1947). Affiliated with the Detroit Edison Co. since 1912, he was elected a Vice-President in 1945. A graduate of the University of Michigan in 1911, Mr. Walker had contributed extensively to the work of various engineering and technical societies, one of which, the American Society of Heating and Ventilating Engineers, gave him the F. Paul Anderson Award for outstanding scientific achievement in this field. In A.S.T.M. he did a great deal to get technical Committee C-16 on Thermal Insulating Materials under way, and was its first chairman, serving two terms. He also participated in other activities.

L. C. CONRADI, Technical Director of Research and Development, Standard Steel Spring Co., Coraopolis, Pa., died December 4, 1947, at his home in Sewickley, Pa., after a long illness. A graduate of the University of Michigan, he was for a number of years Technical Research Manager of the International Business Machines Corp., Endicott, N. Y. He was active in various societies, and in A.S.T.M. served on several committees including D-11 on Rubber and Rubber-like Materials, of which committee he was Chairman from 1928 to 1930. He had been a member of A.S.T.M. since 1928.

T. W. FISHER, Assistant Engineer of Tests—Chemical, The Pennsylvania Railroad Co., Altoona, Pa. (September 5, 1947). Member since 1944, and active on many technical committees, including A-5 on Corrosion, B-2 on Non-Ferrous Metals and Alloys, D-1 on Paint, D-11 on Rubber, and E-3 on Chemical Analysis of Metals.

A. T. KROGH, Liaison Engineer, Westinghouse Electric Corp., Feeder Division, East Pittsburgh, Pa. (September 18, 1947). Member since 1939.

STANLEY M. HANDS, Materials and Testing Engineer, City of Oakland, Engineering Laboratory, Street Dept., Oakland, Calif. (November 7, 1947). Representative of City of Oakland membership for several years.

G. G. POWELL, Commissioner of Works and City Engineer, City of Toronto, Ontario, Canada. Representative of City of Toronto membership.

H. E. ZUMBRUN, President, Morehouse Machine Co., York, Pa. Representative of Morehouse Co. membership.

ROBERT R. GRANGER, Metallurgist, Struthers Wells Corp., Titusville Forge Div., Titusville, Pa. (December 7, 1947). Member since 1946.

L. E. POWER, Chief Chemist, Allen-Bradley Co., Milwaukee, Wis. Member since 1927.

C. L. HENDERSON, President, The Vickers Petroleum Co., Inc., Wichita, Kans. (August 26, 1947). Member since 1925.

LESTER KIRSCHBRAUM, Chemical Engineer, La Canada, Calif. (September, 1947). For many years Vice-President and Director of Research of Flintkote Co., and active in many A.S.T.M. affairs. Member since 1909, and long-time member of the following committees: D-1 on Paint, D-4 on Road and Paving Materials, and D-8 on Bituminous Waterproofing and Roofing Materials.

ALFRED SUTER, well-known textile engineer and manufacturer, New York City, died October 23, 1947, at New Rochelle Hospital following a long illness. He had been a member of A.S.T.M. since 1916 and an active member of Committee D-13 on Textile Materials since 1924.

In the death of Mr. Suter the Society loses an extremely loyal member who had a very high regard for the activities of the Society in all its branches. While his principal interest was in the textile field, nevertheless he had keen knowledge of testing problems in other work. One of the foremost designers of testing equipment, he had a very profound knowledge of this field. A most friendly and understanding individual, he always was willing to help others. His activities and interest in the field of testing and equipment are evidenced by the numerous constructive contributions he made in his chosen field.

A native of Zurich, Switzerland, he came to the United States in 1904 to establish a textile machinery importing business in New York. He had gained a long practical experience in this field in association with his father in Lyons, France. During the first World War he began manufacturing testing machinery in this country, a business in which he was a leader until his death.

Notes on Laboratory Supplies

Catalogs and Literature; Notes on New or Improved Apparatus

NOTE FROM THE EDITOR—In addition to a listing of catalogs and literature received at A.S.T.M. Headquarters, this column will in the future include notes of new and modified instruments. This information will be based largely on literature disseminated by apparatus manufacturers and laboratory supply houses. The purpose of this information in general is to post our members and BULLETIN readers on developments in the industry and to enable them to procure literature direct from the source.

Catalogs and Literature:

LEEDS & NORTHRUP CO., 4902 Stenton Ave., Philadelphia 44, Pa. The latest Leeds and Northrup folder, "Modern Precision," describes numerous instruments used in materials testing and research, including creep testing controls, and pyrometer uses, pH equipment, and other items, such as dielectric measurements and insulation tests.

Also, a 16-page booklet, Catalog ND44-(2) entitled "Micromax Model R Indicating Recorders and Controllers," for the use of instrument men in scientific laboratories and industrial plants. This catalog is not limited to those instruments used to measure any one quantity, but it presents all Micromax Model R's, regardless of whether they are supplied to measure temperature, through the use of thermocouples, Rayotubes, or Thermohms. Illustrated.

Catalog T-623 entitled "Homocarb Method for Carburizing and Gas Cyaniding," 26 pages, describes for the first time how numerous Homocarb furnaces are now being used for gas cyaniding, and provides up-to-date information about the latest improved equipment for carburizing steel. Installation photographs of Homocarb furnaces are included, and the improved Homocarb control panel complete with Micromax Electric Control, time clock, accessories, and its related contactor cabinet is also described and illustrated.

CORNING GLASS WORKS, Corning, N. Y. Catalog No. LP28, "Laboratory Glassware" covers Pyrex, Vycor, and Corning Brands. This 176-page catalog is divided into seven parts, as follows: Part I—Pyrex Brand Laboratory Ware; Part II—Vycor Brand Laboratory Ware; Part III—Pyrex Brand Fritted Ware; Part IV—Pyrex Brand "Lifetime Red" Low Actinic Ware; Part V—Corning Brand Alkali Resistant (Boron-Free) Ware; Part VI—Pyrex Brand Pharmaceutical Ware; and Part VII—Pyrex and Vycor Brand Tubing and Rod. Detailed descriptions of all kinds of glass bulbs, tubes, cups, flasks, etc. Illustrated. Complete subject index given in the back of the catalog.

BURRELL TECHNICAL SUPPLY CO., 1942 Fifth Ave., Pittsburgh 19, Pa. Bulletin No. 206, "Burrell CO_2 Indicator," describes and illustrates this indicator which is used by the operating, installation, and combustion engineer. Four pages.

Also, Bulletin No. 207 describing the "Burrell 'Wrist-Action' Shaker," with a finger-grip clamp for shaking any size volumetric flask. Four pages, illustrated.

BAUSCH & LOMB OPTICAL CO., Rochester 2, N. Y. A new booklet on the subject "Binoculars and How to Choose Them," is divided into several sections or chapters covering the following: Inside Information on Binoculars; Why You Will Choose a Bausch & Lomb Binocular; Balcote Anti-Reflection; Hard Surfacing; What Model to Choose; Binocular Models; Binocular Accessories; Spotting Scopes; Back of Bausch & Lomb Binoculars; Ray-Ban Sun Glasses. 32 pages, illustrated.

BUEHLER, LTD., 165 W. Wacker Drive, Chicago 1, Ill. A four-page folder describing and illustrating AB Diamet Hyprez—a diamond polishing compound for metallographic specimens. The recent introduction of diamond dust for this type of work has met with great success and should interest practically all metallurgists.

HENRY A. GARDNER LABORATORY, INC., 4723 Elm St., Bethesda 14, Md. Two leaflets, one describing "Boston-Bradley Adjustable Blade for Laying Down Films of Any Desired Thickness" and the other, "Interchemical Direct Reading Wet Film Thickness Gage," have recently been made available by this Laboratory. Details of each apparatus are given and each leaflet is illustrated.

GENERAL ELECTRIC CO., Schenectady 5, N. Y. A 44-page catalog entitled "Specialized Testing and Measuring Equipment Catalog," giving information on more than 90 modern equipments for specialized testing and measuring. The products in the catalog are grouped under functional or "use" headings, such as "Time, Speed, and Torque" which arrangement simplifies locating specific products of interest. Equipment covered includes Magnetic; Force, Strain, and Thickness Gages; Color, Light and Spectro Equipment; Chemical Analysis, Resistance and Insulation Testing, Materials Testing, Vibration, Sound and Balancing Equipment, etc. Illustrated.

JARRELL-ASH CO., 165 Newbury St., Boston 16, Mass. JACO Catalog No. I-3 describing Spectrographic Equipment for research in spectroscopy and for spectro-

chemical analysis in metallurgy, mineralogy, agronomy, chemistry, medicine, and other fields. 20 pages, 8½ by 11 in., illustrated.

Eastman Kodak Co., X-ray Division, Rochester 4, N. Y. A new 16-page illustrated catalog entitled "Kodak Materials and Accessories for Industrial Radiography" includes listings of films, exposure holders, intensifying screens, chemical preparations for processing, darkroom accessories, and viewers. A chart indicates the relative speed and contrast of different types of X-ray films for computing exposure.

Haydon Manufacturing Co., Inc., Torrington, Conn. A new 16-page catalog entitled "Haydon Timing Motors and Devices" is complete in every detail with photographs, profile drawings, shaft drawings, and complete listings of the speeds, voltages, frequencies, shaft sizes, and all other standard or special variations available in each motor listed. The catalog is divided into separate sections or data sheets for each of nine different motor series manufactured, and for the various types of timing devices, such as repeat cycle and reset timers, time delay relays, interval timers, elapsed time indicators, etc.

The Emil Greiner Co., 161 Sixth Ave., New York 13, N. Y. Bulletin ICM 96, "Automatic Vacuum and Pressure Control—for Industry, Pilot Plant, Laboratory." This particular Bulletin describes the Cartesian Manostat—Model No. 5, Industrial, a pressure-controlling device based on the Cartesian Diver Principle. Illustrated with graphs and charts, and designs and photographs. Eight pages.

Also, a one-page leaflet describing the Gilmont Ultra-Microburet which gives rapid, convenient titration. Ease of operation is stressed.

Voland and Sons, Inc., New Rochelle, N. Y. A six-page folder describing "Analytical Balances." Illustrates, describes, gives prices, and features of Voland Balances.

Arthur H. Thomas Co., West Washington Square, Philadelphia 5, Pa. A twelve-page folder entitled "Stormer Viscosimeter Including Outfits and Accessories for Various Specific Purposes" describes and illustrates this instrument. Also shows accessory and replacement parts, including the new timer for speeding and improving the accuracy of the paint emsistency test.

Scientific Glass Apparatus Co., Inc., Bloomfield, N. J. Bulletin G-101, "Gyco Heating Jackets for the Laboratory," a 16-page folder giving six major features of the jackets, and other details. Illustrated profusely.

The R. Y. Ferner Co., 110 Pleasant St., Boston 48, Mass. Catalog 100C covers Small Precision Instrument Screws, Nuts and Small Tools for the manufacturer, instrument maker and repairman. Illustrated.

Kimble Glass Division of Owens-Illinois Glass Co., Box 1035, Toledo 1, Ohio. A new Catalog of Laboratory Glassware, illustrated, with 176 pages, and including an alphabetical index. New prices are announced in a separate 44-page section contained in a pocket on the inside back cover of the catalog. This section is arranged by catalog numbers and also serves as a numerical index. Revised price lists are to be issued as required and the price section of the catalog can be kept up to date by merely replacing the old list with the current one. Wide distribution of the catalog is being made throughout the research, control, and analytic laboratories of science and industry. The familiar comprehensive lines of Kimble Blue Line Exax Retested and Precision Normax graduated ware and Kimble Brand ungraduated ware are fully covered. For the first time the catalog includes a complete listing of Kimble hydrometers and thermometers for laboratory use.

Krouse Testing Machine Co., Columbus, Ohio. A new house organ is being issued by this company entitled "Krouse Test Talk." The object of the publication is the presentation of developments in the field of fatigue testing. The first issue describes the new repeated stress testing machine built for Purdue University, and Glen Krouse, the President and founder, has an interesting article tracing the early Wohler tests down to fatigue testing data.

Instrument Notes:

New Model Baldwin-Emery 300,000 lb. Cement and Concrete Testing Machine—The Baldwin Locomotive Works, Philadelphia 42, Pa. Features a 10-in. ram stroke and offers as optional equipment, a spherically seated rectangular compression head, and bearing plate large enough to permit testing of concrete blocks 12 in. wide, 18 in. long, and 8 in. high. Scribed concentric circles on the plate make it equally suitable for standard cylindrical specimens.

Conversion Chart for X-ray Diffraction—X-ray Division, Eastman Kodak Co., Rochester 4, N. Y. Chart permits rapid calculation of exposures with films of varying characteristics of speed, contrast, and graininess. Where a basic exposure for diffraction has been determined using a given film, the chart provides conversion factors by which exposure for any of five types of film may be computed easily. Chart also supplies factors which indicate the increase in relative film speed obtained by eight minutes' development in comparison with normal development of five minutes. This permits decreasing exposure time by as much as 15 per cent, depending upon the particular film.

Gear Gage Paper Weight—George Scherr Co., Inc., 200 Lafayette St., New York 12, N. Y. This device serves as a paper weight combined with a set of gear gages, made of highly polished stainless steel. The set is composed of twelve leaves which include 24 different gear shapes of the following diametrical pitches: D. P.—3-4-5-6-7-8-9-10-11-12-14-16-18-20-22-24-26-28-30-32-36-40-48-64. The gear gages may be used for a quick check of gears. The gages are made in 14½° pressure angle, but if desired may be made to order in 20° and circular pitch. Other shapes or templets, concave or convex forms can be furnished to special order.

Schiefer Abrasion Testing Machine—Sherman W. Frazier, Washington 3, D. C. This machine produces uniform abrasion over a plane area of a specimen from every azimuthal direction. It is based upon the mathematical solution recently worked out by Dr. Herbert F. Schiefer, Physicist at the National Bureau of Standards, to obtain uniformity of wear, exluding any preferential direction.

Dial Type Pocket Thermometer—Scientific Glass Apparatus Co., Inc., Bloomfield N. J. This instrument is ready for temperature checks in the laboratory or wherever temperature control is important. It incorporates features of the popular larger model used in many laboratories. It is unbreakable and is therefore valuable where a product might be ruined by the breaking of a mercurial thermometer bulb. All metal construction of corrosion-resistant stainless steel assures dependable service. Accuracy is guaranteed to ½ of 1 per cent of the entire scale range. This thermometer has a stem ⅛ in. in diameter and 5 in. long. The dial is only one inch in diameter and is protected by an unbreakable plastic crystal. The black figures on the clearly calibrated scale are easy to read.

Table Model Ultra-Sonorator—Fisher Scientific Co., 717 Forbes St., Pittsburgh 19, Pa. The instrument, for generating supersonic energy, is a single-frequency generator which operates on any a-c. line and produces vibrations of 400 kilocycle frequency. This Ultra-Sonorator makes it possible for many more industrial plants, educational institutions, and research foundations to explore the applications of supersonics to chemical, physical, and biological problems. The instrument consists of two units, one the generating circuits and the other an oil bath in which the sample is placed. There are only two controls and the amount of power generated is believed suitable for most research work. Once the instrument is set up, experiments are conducted merely by placing the sample (contained in an Erlenmeyer flask or other flat-bottomed vessel) in the "fountain" produced by the instrument.

Open Bench Unit—also Fisher Scientific Co. This Unit now makes it possible for laboratories to assemble a series of workbench units which will fit any wall space exactly. It not only is adjustable in width to make this perfect fit possible, but also is adjustable in height and serves as a convenient support for analytical balances, microscopes, and other instruments which are employed by the operator when he is in a sitting position.

Cutscum—available for the first time from Fisher Scientific Co. and Eimer and Amend, 635 Greenwich St., New York 14, N. Y., a "soapless" soap in concentrated form particularly recommended for washing laboratory glassware. A major advantage of the new detergent is that it cannot form insoluble precipitates with calcium and magnesium. Also it has a pH value of 6.3 making it entirely harmless to the hands. It is furnished in eight-ounce bottles and only 3 ml. of the concentrated solution is required per two gallons of wash water.

Papers Paged Consecutively

Starting with this issue, the technical papers, which since March, 1947, have been segregated at the back of the Bulletin, will be numbered consecutively throughout the year using TP numbers. This is being done to simplify reference to technical papers and provide continuous pagination for those who remove papers for permanent filing. This new plan for the paging of technical papers is one of the outgrowths of a study being made by the Society's Committee on Papers and Publications to determine the best plan for publishing A.S.T.M. papers.

Symposium on Flammability

EDITOR'S NOTE.—This Symposium on Flammability was presented on October 16, 1947 at an afternoon session of the three-day series of meetings held by Committee D-13 on Textile Materials in Philadelphia. The symposium was held in cooperation with the A.S.T.M. Philadelphia District Council. The Program Chairman for the Symposium was R. T. Kropf, Director of Research, Belding Hemingway Corticelli Co.

Included in the Symposium are the following papers:

Flammability of Textiles for Garment Purposes—Frederic Bonnet
Flameproofing in Theory and Practice—R. W. Little
The Retailer's Viewpoint on the Flammability of Textiles—C. W. Dorn

Flammability of Textiles for Garment Purposes

By Frederic Bonnet[1]

FLAMMABLE fabrics may be defined as those which catch fire readily and burn rapidly. The flammability is dependent not only on the kind of fibers used but to a very large extent upon the construction of the fabric.

The natural fibers, wool, and silk, do not burn readily. This is also true of such fibers as nylon, "Vinyon," acetate rayon, and the protein, or Azlon, fibers made from casein, soybeans, corn, peanuts, etc. With a rise in temperature they tend to melt and mat together thus preventing the ready access of air.

The cellulosic fibers, like cotton, linen, ramie, and the regenerated cellulose types of rayon do not melt, and the air has more ready access during their burning. It is from this group of cellulose fibers that most of the flammable fabrics are made. Whether such fabrics may be considered dangerously flammable depends primarily upon their construction, for the rate of burning will depend upon how tightly or how loosely the fibers are held together in the fabric. If the fibers are tightly twisted together and woven into a tight fabric, like canvas, then ignition is not easy and initial burning slow.

If, on the other hand, the yarn has an open, loose twist, and the weave is open and sleazy, or if the surface is brushed out, or has a deep pile, or if the fabric is a fine light fabric, then ignition is easy and the burning rapid and too dangerous for certain types of fabrics to be used for garment purposes. In illustration, the following three accidents may be cited. A young stenographer was severely burned when in striking a match to light the kitchen gas range the head flew off and ignited the angora type sweater with long fuzzy nap that she was wearing. The burning was so rapid and intense that she could not beat out the flames nor could the sweater be removed with the help of her sister and brother-in-law (both of whom were also quite severely burned) before serious injury had been done. She was not only badly burned and quite disfigured, but the accident permanently hinders the full use of her hands.

The second example is that of an 18-year-old University of Texas co-ed, whose thin, filmy dress caught fire when it brushed against a lighted candle during a sorority initiation and burned so rapidly that she died of her burns the following morning.

A third example of flammable fabrics is the case of a young woman in Washington, D. C., who was severely burned when her chenille lounging robe caught fire. She sued the department store from which the garment had been purchased for $50,000 damages and the U. S. Court of Appeals ruled that "since outer garments, intended for domestic wear, are not unlikely to come into momentary contact with lighted matches, tobacco, or stoves, it seems to us clear that a robe which, when this contact occurs, instantly bursts into flame and inflicts severe in-

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] American Viscose Co., Marcus Hook, Pa.

jury, is unreasonably dangerous and unfit for use." This opinion was upheld by the U. S. Supreme Court.

These three examples have been chosen (and many, many more could, of course, be cited) because they represent three types of flammable fabrics. The first was a long-napped brushed or pile rayon fabric; the second was a delicate fine mesh, net or sheer fabric made of rayon or cotton; and the third was a tufted cotton fabric. In each case the air had ready access to the fibers or fine-sized yarn, so that the fabrics burned rapidly once they had become ignited. The third example was also chosen because it brings out the responsibility of merchants, under warranty, in selling dangerous merchandise.

Another type of flammable fabric is one in which a cotton or rayon fabric, which ordinarily would not be considered flammable, is made so by treating or coating it with a flammable material such as pyroxylin. To this type of flammable material might be added certain plastic films which not only ignite quite readily but melt rather easily and the burning blobs of liquid inflict deep and painful burns where they fall upon the skin.

Burning accidents seemed to be very much on the increase, especially those concerned with garments. It was the indignation of a California mother which led to the passage of the California law.

She had purchased a chenille dressing robe for her small daughter and when she got home found a tag on it advising that the garment be kept away from open fires. She visualized the danger and was indignant that such garments should be sold which endanger the lives of women and children.

The California law as first drawn up made it "unlawful to manufacture, sell, or offer for sale any article of wearing apparel, cloth, drapery, etc.,...more highly flammable than cotton cloth in its natural state."

Unfortunately, comparing the flammability to cotton cloth in its natural state was too vague and uncertain to make such an act enforceable. However, in an amended form, this bill was signed by Governor Warren in June, 1945, and included fabrics and garments made of either natural or "synthetic" fibers proven to be flammable by tests to be made by the State Fire Marshal.

What was urgently needed was a reliable testing method by means of which the rate of burning of any fabric could accurately be measured and determined. Having determined the relative rates of burning, it would then be possible to decide which fabrics burn so rapidly that they constitute a definite fire hazard, especially when used in garments, and should therefore be outlawed. Realizing not only the need of a testing method, but also that one should be obtained as soon as possible since both state and national legislation were pressing, Dr. L. A. Olney, chairman of the Research Committee of the American Association of Textile Chemists and Colorists, appointed a committee to investigate the matter with H. E. Hager as chairman. This was done shortly after the original Fabrics Flammability bill was introduced into the California Legislature in January, 1945.

The committee's work resulted in developing the tester and method of test which is described in detail in the 1946 Yearbook of American Association of Textile Chemists and Colorists and also in the Recommended Commercial Standard TS-4350 for Flammability of Textiles. Appended to this paper are the Operating Instructions and Test Procedure for A.A.T.C.C. Flammability Tester.

In developing this A.A.T.C.C. fabric flammability tester, one of the first considerations was to determine whether a flame or the radiant heat of a glowing wire should be used as the source of ignition. A flame was decided upon as this seemed to be the most common cause of fabric ignition. In many reports of accidents, a glowing cigarette is blamed for setting fabric afire, but the committee was never able to get ignition even of delicate fabrics when exposed to the glowing end of a cigarette.

Another question that arose was whether the sample should be tested in a vertical, a horizontal or some other position. Tests showed that in the vertical position almost all samples burned so rapidly that it was difficult, if not impossible, to determine a difference in the rate of burning. Horizontal tests, on the other hand, were rather slow burning and did not give proper results with tufted fabrics that seemed to burn at about the normal rate of the backing cloth, and yet tufted and chenille types of fabric were known to be dangerously flammable. A 45-deg. angle, that is halfway between the horizontal and vertical method of testing, was therefore chosen as it gave a good rate of burning, yet made it quite possible to measure the different rates of burning.

The next question was the size and kind of flame to use as many accidents seemed to have been caused from the flame of a match, so a flame about $\frac{5}{8}$ in. in length was chosen. To get a uniform flame intensity, pure butane, which can now be readily obtained in small cylinders at nominal cost, was chosen.

It was also important to determine the length of time the flame should be left in contact with the sample. A piece of 80 square cotton sheeting which, of course, will burn but which cannot be considered flammable, was chosen as a standard in determining the time of flame contact. If the butane flame is allowed to impinge on a duly dried and prepared sample of this sheeting for one second, it will be scorched at the point of flame contact but not be set on fire, and samples under test would thus be exposed to the same heat intensity for the same length of time.

A troublesome question was how best to condition samples so as to get check results. The committee felt that since practically all bad accidents had happened while the fabrics were dry, testing should be done under the most dangerous condition, namely, dry, which is a condition incorporated in the test method.

In order to check the testing method itself, seven machines were built and were distributed among seven laboratories. With the details of the machine worked out, several types of brushed fabrics

were obtained and samples of these were distributed to the different laboratories for test. Much to the surprise and disappointment of the committee, the different laboratory results did not check. Then began the long task of studying sample preparation and conditioning for test. The condition of the fabric surface was found to be one of the critical factors which led to the development of the combing device.

While all this work was going on, the matter of flammable fabrics was suddenly and tragically brought to the attention of Congress and the nation in early April, 1945, when three small boys were burned to death and some seven others injured right in Washington when their cowboy suits caught fire while playing around an unattended brush fire. This focused attention on flammable fabrics and prompted demands for restrictive legislation. Congressman LeRoy Johnson of California had already read a bill to outlaw flammable fabrics that was essentially the same as the original California bill in which all fabrics were "compared to cotton cloth in its natural state."

Lest unwise legislation be forced through Congress, an informal meeting in Representative LeRoy Johnson's office was arranged for by the National Retail Dry Goods Association where Cameron Baker demonstrated the A.A.T.C.C. machine. Members of the committee made it clear that before any legislation could be effective a suitable test method would first have to be devised and this would take some time. Testimony also brought out the fact that the flammability of a fabric was not necessarily due to the kind of cellulosic fibers, whether cotton, linen, ramie, regenerated type of rayon, etc., of which the fabric was made, but upon the construction of the fabric, as already mentioned. By means of the tester the relative burning rate of various types and kinds of fabric could be determined.

The final question was which should be considered too hazardous to be worn for outer wearing apparel? To answer this question was not easy. However, the committee obtained samples of fabrics from garments which had actually been worn at the time of accidents. If such actual fabrics were not available, samples of new material of which the accident fabric had been made were obtained. Checking as many such samples on the A.A.T.-C.C. tester as possible, the committee found that fabrics tested under the standard conditions of test, which were readily ignited by the one second contact of the standard flame and burned 5 in. in 2 sec. or less, had definitely caused serious and some fatal accidents. Fabrics which had a rate of 5 in. in 4 sec. were in their opinion, too near to the borderline of dangerous fabrics to be considered safe. In consequence, fabrics rated at 5 in. in 6 or more sec. were considered safe for wearing apparel.

Cases are on record where nitrocellulose-coated fabrics have been the cause of fatal accidents. For example, in one case the coated material was made into an apron and when wrapped around the hand to "protect" it while removing baked bread from a hot oven it burst into flame resulting in panic and a painful death of the victim. Then there is the report from the California State Fire Marshal in December, 1946, which told of a fatal accident when a little five-year-old girl in Whittier, Calif., backed into an electric radiant heater and ignited her raincoat.

The A.A.T.C.C. method has also been turned over to the National Bureau of Standards, Division of Trade Standards and a tentative Commercial Standard TS-4350 entitled Flammability of Textiles, has been sent out for approval. Three bills concerning flammable fabrics were introduced at the last Congress. Two bills, one by Representative LeRoy Johnson of California and one by Representative Canfield of New Jersey, are quite similar but they unnecessarily take in a great many fabrics. A third bill, restricted to wearing apparel, was introduced in the House by Representative Wat Arnold of Missouri and the same bill went to the Senate and was introduced by Senator Capehart of Indiana. This bill, which had been worked over with some seven revisions, is sponsored by the National Retail Dry Goods Association. A hearing before the Interstate and Foreign Committee, to which the bills were referred by the House, was held last March which brought much interesting evidence.

No doubt bills concerning flammable fabrics, quite aside from the general interest which the California law and the proposed Federal bills have aroused, are causing manufacturers, converters, and retailers to wonder whether their merchandise is legal in California. The enforcement of the California law was placed in the capable hands of the State Fire Marshal, Joe R. Yockers, whose very fair interpretation of the law has greatly eased the fears of the textile trade. However, this state law poses the question as to what the result will be if each of the 48 states passes its own flammable fabrics law, with various interpretations and enforcements.

In view of this, the California legislature has memorialized President Truman to have Congress pass a Federal law for uniform enforcement. It remains to be seen whether there is to be a Federal law, whether industry will enter upon an educational program as suggested by the various cotton groups, or whether some form of approved labeling program for flammable fabrics will be put in effect.

But in any case, the interest which has been aroused due to the increase in painful, disfiguring, and all-too-frequent fatal accidents makes it seem most likely that some form of protection will be enacted by Federal legislation or by voluntary agreement in the industries involved.

APPENDIX

Operating Instructions and Test Procedure for A.A.T.C.C. FLAMMABILITY TESTER[1]

Tentative Test Method

Scope:

The object of this test procedure and the Flammability Tester is to evaluate textile materials for flammability characteristics by measurement of rate of burning.

1. Test Apparatus (Description of Flammability Tester):

A. Draftproof Chamber with Adjustable top.
   1. This metal chamber prevents air circulation around the specimen rack and flame, but permits free ventilation for rapid oxidation.
   2. The top is adjustable and removable.

B. The specimen rack is fixed at an angle of 45 deg. and consists of a 4 by 7-in. framework strung with heat transmitting wire laced horizontally.

C. Specimen Shield.
   1. This shield, controlled by a hand lever, covers all but 1½ in. of the width of the test specimen for the full length.
   2. Shield is raised for the insertion of test specimens and must be brought to bear on the sample face before the start of the test.

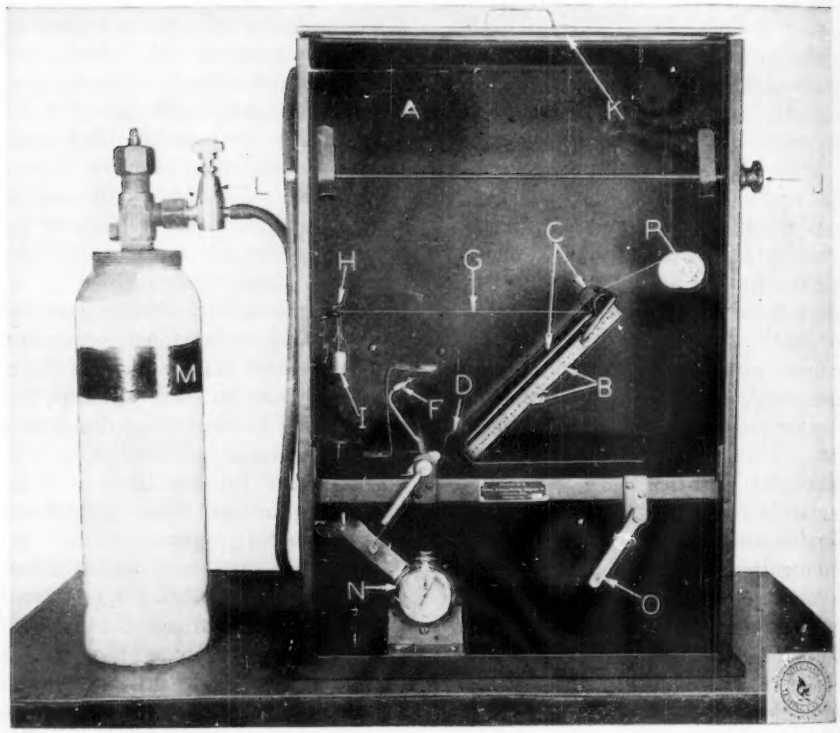
D. Indicating Finger.
   1. The forepart of this finger rests on the wire lacings when the sample rack is brought all the way forward.
   2. By means of this finger, the thickness of the sample is compensated for in the throw of the gas nozzle.

E. Control Knobs (Not Shown).
   1. There are two of these knobs which hold the rack in test position.
   2. The knobs can be reached under the stage of the cabinet and permit forward and backward movement of the rack when loosened.

F. Gas Nozzle.
   1. The gas jet consists of a 36-gage hypodermic needle protected by a copper shield formed around it.

G. Stop Cord.
   1. This cord stretched from the spool *P* down over the top of the rack and through the loops in the shield and across to the stop mechanism measures the vertical height of the flame.

H. Pulley or Eye.
   1. Support and guide for stop cord.



Flammability Tester

I. Stop Weight.
   1. The weight attached by means of a clip to the stop cord, in dropping, actuates the stop motion.

J. Slide Door Control.
   1. This knob moves the catch mechanism used to hold the sliding door (not shown in actual position) in an open condition for insertion of test specimens.

K. Slide Door.
   1. A glass door (shown in end view) in its normal position slides in the grooves at the front of the cabinet.

L. Fuel Control Valve.
   1. Consists of a sensitive control device for regulating the fuel supply at the tank.
   2. The valve ends in a ½-in. female connection for attachment to the standard butane tank of two pounds capacity.
   3. A flow meter (not shown) is used to bring the fuel supply to test level by means of the control valve.
   4. The flow meter consists of a U-shaped glass tube cut into the gas line in a manner to register the gas pressure delivered to the microburner. Attached to the case wall behind the flow meter is a movable metal plate with two parallel horizontal lines one inch apart. When the pressure is off, the plate is so regulated that the liquid level in both sides of the U-shaped tube meets the lower line. When the test is made the pressure is so adjusted that the highest liquid level in the U-shaped tube meets the upper line.

M. cp. Butane Container.
   1. This fuel supply, which is not furnished as part of the test equipment, is a No. 4 cylinder of cp. butane.

N. Stop Watch and Timing Mechanism.
   1. This watch, by means of special attachments, is actuated to a start by connection with the gas jet *F*.
   2. A driving mechanism on rear of cabinet (not shown) moves the gas jet to its most forward position and automatically starts the timing at the moment of flame impact.
   3. The falling weight *I* when caused to move by severance of cord *G* stops the watch.

[1] Reprinted from *Proceedings* American Association of Textile Chemists and Colorists.

4. Timing is read directly.

O. Starting Lever.

1. This lever is operated from left to right in one stroke and is released to operate the gas jet.

P. Cord Supply.

1. This supply, consisting of a spool of No. 50's mercerized cotton sewing thread, is fastened to the side of the chamber and can be withdrawn by releasing the thumb screw holding same in position.

Q. Cord Loop.

1. At a point behind *G* on the rear panel, there is installed another loop (not shown in cut) to draw the cord away from directly over the flame.

R. Draft Ventilator Strip.

1. A draft ventilator strip (not shown in cut) is placed across the front opening, sealing the space between the sliding door when in lowered position and the base on which the grid rack is attached.

II. Description of Combing Device:

As shown in the photograph, this apparatus consists of a base board over which a smaller carriage is drawn by means of a counter weight. This carriage runs on parallel tracks attached to the edges of the upper surface of the base board. The comb is hinged with pin hinges at the rear edge of the base board and rests on the carriage with a pressure of 200 g.

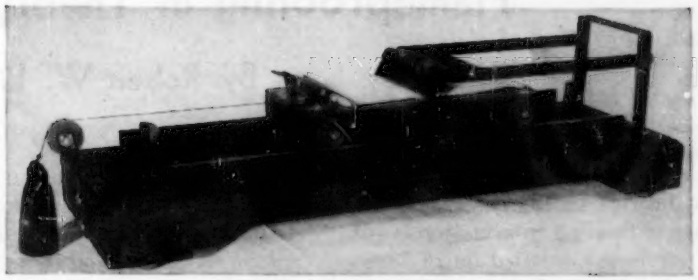
After the sample has been put in place on the carriage and fastened by means of the clip, the comb is raised, the carriage pushed to the rear, the comb lowered to the face of the sample. The carriage is then released and is drawn forward by means of the 228-g. weight attached to the front end of the carriage by a cord. This cord runs over a grooved pulley as a guide and allows for free running of the carriage.

III. Pretesting of Fabrics:

A piece of the material in question (2 in. by 6 in.) is combed, dried, desiccated, and tested on the apparatus to determine whether said fabric is flammable. If the fabric does not burn, or burns very slowly, a piece of fabric large enough for the required number of tests is washed by the following procedure.

IV. Washing Procedure:

Make up a bath containing 0.5 per cent neutral chip soap, volume of bath 30 times the weight of material. Warm the bath to 95 to 100 F., immerse the material, and work gently by hand for 5 min. Rince twice in clear water at 80 to 85 F., extract and dry.

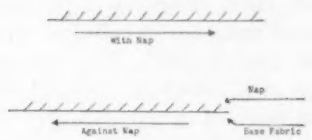


Combing Devices

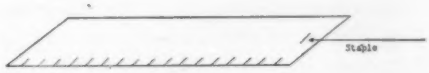
The fabric is then tested by the regular procedure. This washing procedure should remove most of the water-soluble fire-retardant finishes.

V. Preparation of Samples:

The direction of the nap face is first determined on receipt of fabrics for test. Terms used:



Mark out on the fabric back, the size of the samples (2 in. by 6 in.) to be used. Mark the individual sample before cutting with a staple as shown by the following sketch.



The required number of samples are then cut. Each sample is placed on the combing device carriage and drawn under the comb once against the lay of the napped face surface. The samples are then placed in an oven at 105 C. for 15 min., removed and desiccated over calcium chloride for 5 min.

Individual samples are then removed from the desiccator, placed on the combing carriage, and drawn under the comb once in the direction of the lay of the napped face surface. The samples are then placed on the grid on the flammability testing device and tested according to the regular procedure as follows:

VI. Direction for Use:

A. The control valve from the fuel supply is opened and adjusted to the test level. Some time has to be allowed in order to drive the air from the fuel lines. This interval should be approximately 5 min. A flame is then applied to the gas nozzle in its starting position. The sample rack with the test specimen in place (stapled end at top of Grid) is brought forward to the point where the indicating finger touches the face of the sample and is then locked. The shield over the test specimen should be in place when this adjustment is made.

B. The cord is strung through the loops in the shield, across the top of the sample, through the loop on the rear panel and over the guide ring and then the weight is hooked in place close to and just below the guide.

C. The stop watch should be set at zero at the start of each test.

D. The slide door should be in close position at the start of the test.

E. Bringing the starting lever over to the extreme right and releasing it will start the timing mechanism that supplies the gas jet to the face of the fabric.

F. Timing is automatically recorded by the watch, starting upon application of the flame, and ending with the cord burning through at the end when the flames reach the cord line which is horizontal to the top of the sample.

G. Tests should be conducted in a draft-free room.

VII. Suggested Interpretation of Test Results:

The results of tests on the five samples are averaged. If the average figure is 6 sec. or higher, the fabric may be considered not dangerously flammable. If lower, the fabric may be considered flammable and unsafe when worn by persons. No individual sample shall show a flammability rate less than 5 sec. If failure occurs on any count, indicating the critical nature of the material, a retest is to be made on five additional samples; and if the material is to be declared acceptable, the average of the entire ten samples is to be 6 sec. or higher and no individual specimen of the second lot of five is to be below 5 sec.

Flameproofing in Theory and Practice

By Robert W. Little[1]

THE treatment of textile fabrics to increase their resistance to flaming combustion is not new, nor is the institution of legislation restricting the use of highly flammable fabrics for certain end-use purposes. Both the technical and legislative aspects of flameproofing, however, have been greatly reactivated in this country in the last five years. The other two papers of this program discuss the status of legislative action regarding flammability, the degree of flame-resistance required for various applications, and the fabrics principally affected. I should like to consider the means of achieving the desired resistance to fire by reviewing briefly the mechanisms by which flame-resistant compounds are believed to function and the practical formulations employed in their commercial applications. Thus far the majority of these more fundamental considerations are confined to cotton and rayon fabrics.

Flameproofing Mechanisms

The chemical nature of the active ingredients of flameproofing formulations and the mechanisms by which they function have been at least partially revealed by the many wartime researches of industrial groups and Government laboratories. The over-all picture of the requirements of a flameproofing agent is that it shall be intimately mixed with the fibers and be capable of performing its function at the time the material reaches flame temperatures. In many cases the actual active ingredient cannot be affixed to the fabric as such due to its fugitive nature or the degrading action it may exert. Therefore, it must be released at the proper time and in the proper place as a result of a reaction occurring at the time of incipient flaming.

When heated to temperatures approximating that of a flame, cellulose is degraded into three phases: a solid char, a volatile liquid of tarry nature, and a gaseous fraction. Several independent investigations have shown that the occurrence of flaming combustion depends upon the relative amounts of these decomposition products and the rate at which they are formed. Since flaming is essentially the rapid oxidation of a combustible vapor, the prevention of flaming could theoretically be accomplished by retaining all decomposition products in the solid and gaseous phases. The ideal case, then, would be a quantitative transformation of cellulose into carbon and water. The absence of any intermediate decomposition products of a combustible nature would preclude the occurrence of a flaming reaction. In actuality, the addition of a flameproofing agent to cellulose does markedly increase the amount of char formed on thermal degradation. Furthermore, the effect is proportional to the efficiency of the material added in actuality preventing flaming in practical burning tests. Contrary to early beliefs, the truly gaseous products do not play a major role in flameproofing reactions. The amount and rate of gas formation are increased upon the addition of flameproofing salts, but there appears to be no change in the flammability of the gases evolved. Even more conclusive is the fact that the effect of salts upon the gases formed is fairly constant irrespective of the efficiency of the compound as a flame-retardant. The volatile, liquid tarry products, on the other hand, are highly combustible and serve as fuel for the flame. The addition of flame-retardant salts reduces the amount of tar formed and the reduction is proportional to the efficiency of the added salt in the prevention of flaming. When actually evolved, the tarry products are accompanied by appreciable quantities of water. At the same time that the amount of tar is reduced by retardant action, the quantity of water formed is materially increased. In summary then, the effect of a flameproofing material upon the thermal decomposition of cellulose is to confine much of the flammable, liquid degradation products to the solid char phase and, at the same time, dilute the remaining combustible vapors with large amounts of water.

Many divergent theories have been advanced to explain these observed effects in terms of chemical and physical relationships between the fiber and the retardant. A purely physical mechanism which has been suggested is the coating of the fiber or thread with a glass-like material that serves as a barrier between fabric and flame. There is evidence to support such a mechanism in many cases, although the nature of the coating appears more often to be foam-like rather than glassy. In agreement with the observed effects, combustible tarry degradation products are apparently entrapped in the coating and further degraded to the gaseous and solid phases.

Many compounds, particularly the ammonium halides and other ammonium salts, are believed to function by the evolution of large quantities of noncombustible vapors which serve to dilute the combustible atmosphere surrounding the fiber. This may well contribute to the over-all effect in many cases. That it is a major factor is unlikely, however, considering the much greater amounts of gases produced by the degradation of cellulose itself.

A third physical mechanism advanced is that some compounds reduce flaming by the absorption of large quantities of heat as a result of physical changes in the retardant. The evidence appears to be against such a phenomenon.

Probably the best existing theories of the manner in which flameproofing agents perform are two which regard the relationship as chemical rather than physical. The

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Director of Research, Ellicott Laboratories, Lawrenceville, N. J.

first of these, in agreement with the ideal case wherein cellulose is transformed to carbon and water, proposes a catalytic dehydration action at flame temperatures. This is strongly supported by experimental data, by the known dehydrative properties of many of the acid anhydrides, and by the relative performance of those salts which can liberate the acid residue on heating as compared with those which are thermally stable.

The same phenomena are interpreted in different terms, according to the second of these theories, as being a question of comparative hydrogen bonding energies. This proposal is also supported by the data available and by the fact that the anhydrides formed from inorganic acids and their acid salts possess high hydrogen bonding activity. The formation at flame temperatures of a residue capable of attracting and holding adjacent cellulose chains would certainly tend to increase the average size of fragments formed and increase the solid char at the expense of the volatile tarry vapors.

The mechanisms discussed thus far have considered only prevention of the flaming of a fabric. It has been recognized recently that the phenomenon of after-glow is an entirely different reaction independent of the after-flaming tendency. Whereas there are innumerable compounds possessing flame-retarding properties, there are very few glowproofing agents and only two theories of their method of operation. Certain salts have been found to produce a more or less continuous film on the surface of the fiber when heated to flame temperatures. Since afterglow is the oxidation of the residual carbon filament, the exclusion of oxygen resulting from such a coating would be expected to reduce the glowing tendency.

A more efficient and better substantiated mechanism is a catalytic effect on the course of the oxidation of carbon. The amount of heat evolved in the oxidation of carbon to the dioxide is approximately 3.5 times that evolved in forming the monoxide. The preferential formation of CO rather than CO_2 apparently reduces the heat evolved to a point where it is insufficient to support a self-sustaining glowing reaction.

In considering the nature of flameproofing compounds and their mode of action, it is apparent that in many cases more than one of the suggested mechanisms may function concurrently. This is particularly true because of the chemical complexity of some of the commercially available flameproofing formulations.

Flameproofing Compositions

The classification of a compound or mixture as a flameproofing agent should be based upon the effectiveness of the material in preventing the flaming of a fabric. The addition of any nonflammable substance will reduce the flammability of a fabric. In order to qualify as a true flame retardant, however, the effects should be obtainable at relatively low add-ons by one of the mechanisms mentioned previously, rather than by merely diluting the combustible material.

Of the many flameproofing compounds now commercially available, the majority consist of water-soluble salts or mixtures which fall into the category of temporary or transient treatments. The grouping of these materials may be based upon their chemical nature and the mechanism by which they are believed to function.

Borax, aluminum sulfate, and mixtures of borax and boric acid or borax and the ammonium phosphates represent the class of retardants which function by virtue of a physical coating phenomenon. These are generally highly hydrated, low melting salts or mixtures. Phosphoric and sulfuric acids and their ammonium salts, ammonium molybdate, zinc chloride, and antimony oxychloride are examples of the group covered by the catalytic dehydration or hydrogen bonding theories. In agreement with the proposed mechanisms, the salts in this category must be capable of releasing the acid anhydride on heating. Finally, the carbonates, ammonium halides, and other ammonium salts fall in the class capable of generating a nonflammable atmosphere when heated.

The temporary, water-soluble treatments possess the advantages that they are easily applied, are extremely effective at relatively low add-ons, and do not greatly affect the desirable physical characteristics of the fabric such as hand and color. The flame-resistant properties are purely temporary, however, and any exposure to water completely destroys the effectiveness of the treatment. Accordingly, these materials are applied with the intention of periodic testing and reprocessing. The most serious disadvantage of the water-soluble salts is their tendency to undergo physical or chemical changes on exposure to high temperatures or humidities or even on prolonged exposure to normal environmental conditions. In many instances, the residue remaining is either no longer effective as a flame-retardant or is acid or basic in nature, thus having a deleterious effect on the fabric. Unless careful periodic testing programs accompany the use of water-soluble salts, considerable uncertainty may exist regarding the flame resistance remaining at any given time in the life of the fabric.

A great many flameproofing compositions have been advanced for imparting more or less permanent flame resistance to fabrics. Relatively few of these, however, have proved themselves capable of practical commercial application. A simple subdivision of the available processes would be those in which the active retardant ingredients are physically bound to unmodified cellulose fibers and a second type which depends for its effectiveness upon chemical modification of the cellulose molecule.

The earliest approach to permanent flameproofing was of the former type, employing a double bath technique. This consists of depositing an insoluble salt in and on the fibers by immersing the fabric in two aqueous solutions, the dissolved solids reacting either at the moment of immersion in the second bath or during subsequent drying. A typical example is the Perkins process wherein hydrated stannic oxide is precipitated by successive immersions in sodium stannate and ammonium sulfate solutions. A novel adaptation of the same principle lies in dissolving both salts in a suit-

able organic solvent, depending upon subsequent exposure to water or to water vapor to bring about the desired interaction. The two-bath processes in general benefit by good penetration and distribution and have relatively little effect upon the hand and appearance of the fabric. In most cases, however, they require moderately high add-ons and are progressively susceptible to laundering. They may be regarded as intermediate between water-soluble salts and the pigment dispersion formulations.

At present, the most common approach to permanent flameproofing is the use of pigment dispersions. In essence, the insoluble retardant is applied to the fabric in a finely divided state by means of solvent suspension or emulsion vehicles. Many types of inorganic and organic flameproofing compounds can be applied in this manner, the most widely used combination in the past being a mixture of metallic oxides and chlorinated waxes or resins. Several commercial products or finishes of this type are available for use today.

The criticisms of such formulations are the high add-ons required and the corresponding effects on the physical characteristics of the fabric. On the credit side there are many advantages. The flameproofing process leaves the fabric with its original tensile strength or it may even produce a gain in strength. The treated fabrics possess the greatest resistance to wet and dry cleaning operations of any of the insoluble flameproofing processes. The compounds are generally very easily applied on available finishing equipment, require only normal drying temperatures, and permit very fast running speeds. Coloring pigments may be included in the formulation, or, where desirable, proper compounding can result in various degrees of stiffness similar to permanent sizing effects. Finally, in the proper selection of fabrics it is possible to turn the loading into material advantage for the finisher or converter, by permitting the use of lower-count, lighter-weight materials for certain end-uses.

The last-mentioned process for obtaining permanent flameproofing, and the latest to be adapted to commercial operations, consists of a chemical modification of the cellulose molecule. The principal application thus far has been the esterification of cellulose with inorganic acids, notably phosphoric. The resulting phosphate ester is rendered resistant to laundering by the formation of complex salts of the unreacted acid groups, the permanence being proportional to the complexity of the amide formed. The principal advantages of this type of process are that efficient flame and glow resistance can be achieved with somewhat lower add-ons than in the case of the pigment dispersion techniques and there is less effect on the physical characteristics of the fabric. Principal criticisms at the present time appear to be related to secondary effects of the esterification reaction. The treatment is accompanied by losses in fabric strength, the strength decrease being proportional to the permanence achieved.

Also, by virtue of the nature of the retardant complex, the treated fabrics possess limited resistance to laundering operations.

During the past year or two, considerable progress has been made in the development of commercial flameproofing compounds and processes. Increased activity on the part of manufacturers of textile auxiliaries and industrial chemicals promises continued refinement of flameproofing materials, but the treatment of fabrics to render them resistant to fire has progressed beyond the novelty stage and materialized as a finishing technique already capable of meeting the majority of requests for its application.

The Retailer's Viewpoint on the Flammability of Textiles

By Charles W. Dorn[1]

FLAMMABLE materials have been defined as those which catch fire readily and burn rapidly. This definition is confined to fabrics and I would like to include articles of adornment such as combs, buttons, etc.

Ten years ago we had a few isolated cases of injury or death from flammable materials. Going back over the records we find instances where people were hurt or killed from the rapid burning of various types of wearing apparel or ornaments. In one case a woman was severely burned around the head when an ornamental comb made of cellulose nitrate was ignited by a candle on a restaurant table. Another accident occurred when the buttons on a woman's dressing gown were ignited. These buttons were made, also, from cellulose nitrate and in the shape of a flower from very thin sheets with serrated edges. There are cases where people were badly burned with negligees or robes and several instances where loosely brushed rayon sweaters caused severe injury. There were also several cases where net evening gowns were involved. One case of this nature happened recently in the town in which I live, that brought home the problem very forcefully.

A local dancing school was having its annual recital and the group participating ranged from very young children to the teen-age or ballroom dancing group. In this teen-age group there was a girl about 14 years old who had on a long net evening gown. During the recital she stepped on an electric cable which fed some of the flood lights. The cable shorted, there was a flash and an electric spark, and she was covered with flames almost instantaneously. Fortunately, the body of the dress was made of acetate rayon, over which the net was draped, and which was completely fused but which, apparently, pre-

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[1] Director Research Laboratory, J. C. Penney Co., Inc., New York, N. Y. Chairman, Technical Committee, National Retail Dry Goods Assn.

vented the spread of fire inwardly, thus preventing serious injury.

There are also numerous cases on record of death or injury from coated materials.

As time went on these accidents became more and more frequent until the National Retail Dry Goods Association took definite steps to try to eliminate the hazard from flammable buttons and ornaments. Numerous conferences were held with the various manufacturers and much was accomplished toward eliminating these articles from use. These accidents, as before stated, became more and more frequent until the whole problem was brought sharply into focus through the death or injury of a number of small boys playing in cowboy suits which were highly flammable. Litigation is pending[2] on the cowboy suit accidents totaling a million and a half dollars. This litigation is not only against the retailer but in many instances includes the cutter and the fabric manufacturer—in fact, anyone who had anything to do with the makeup of these garments.

It is obvious from the above conditions that something had to be done to remedy this situation.

Much has been said in regard to the responsibility, legally and financially, in case of such accidents. Mr. Bonnet has mentioned a case in Washington, D. C., where the retailer was held liable on implied warranty that a garment was fit for the use intended and that the fact that it was highly flammable made it unfit for such use. Let us not forget, however, that if this implied warranty applies between the retailer and the customer, it will also apply between the retailer and the manufacturer. Regardless of where the fault lay, the National Retail Dry Goods Association took steps to do what it could to remedy this very serious situation.

The Association first got in touch with the American Association of Textile Chemists and Colorists and requested that this organization set up a committee to develop test methods which would differentiate between hazardous and relatively nonhazardous materials. This committee, within 18 months, devised a method of test which was turned over to the Trade Standards Unit of the National Bureau of Standards with the request of the National Retail Dry Goods Association that it be made into a Commercial Standard. In the meantime, a law was enacted in the State of California which prohibited the sale of flammable materials. The law itself was not limited in scope to wearing apparel, but, fortunately, when the Fire Marshal, as empowered by the legislation, issued his Rules and Regulations, they applied only to wearing apparel. If this had not been the case there would have been many fabrics and articles which had been used for many years without causing trouble, affected by this law.

Two bills were introduced in the Congress, one by Representative Leroy Johnson of California and one by Representative Canfield of New Jersey. These bills were quite similar but took into consideration an unnecessarily large number of fabrics. Both of these bills used a test developed by the National Bureau of Standards to determine whether or not the fabric would be considered flammable. Neither of these bills was considered sound, so the National Retail Dry Goods Association drafted a third bill restricted to wearing apparel and relying on the proposed Commercial Standard for the test method. This bill was introduced into the House of Representatives by Representative Watt Arnold of Missouri and in the Senate by Senator Capehart of Indiana.

Hearings were held on all three of these bills by the House Interstate and Foreign Commerce Committee, but no Senate hearings were held.

At the House hearing there was a great deal of argument concerning test methods and whether or not a method was available that was sufficiently accurate to serve the purpose.

In the meantime the Commercial Standard had not been approved by industry and a Standing Committee including all interested parties was set up by the National Bureau of Standards for the proposed Commercial Standard. This Standing Committee later appointed a Technical Committee to study the proposed Commercial Standard and to see if proper correlation could be obtained in a number of laboratories on the same fabrics using the method as described in the Commercial Standard. Seven laboratories were involved in these tests and the reports have just been received within the last few weeks. Analysis of these reports shows that in most types of fabrics fairly good correlation was obtained, but in one type there was a wide variation in results. It is obvious that additional work must be done on this standard. We are unable to state, at the present time, whether the variations encountered are due to irregularities in fabric or whether there is some difference in the method used by the various laboratories or whether there is some slight difference in the various machines used. As before stated, more work will be required to determine just what is the difficulty.

At this point I wish to call your attention to the fact that *this is the only test method which has been subjected to a series of tests in an attempt of correlation.* A test developed by the Bureau of Standards has never been subjected to such study and we have no way of knowing whether correlation will be possible with this method. Until very recently only one machine of this type known as the horizontal tester, had been built. We understand now that there are five or six machines available which can be sent around to various laboratories for an attempted correlation.

Let us review briefly the various phases of the flammability question as we find them today.

1. *National Legislation.* Three bills were introduced last year, namely, the Canfield bill, the Johnson bill, and the Capehart-Arnold bill, sponsored by the National Retail Dry Goods Association. We have heard that Representative Johnson has ammended his bill so that it applies only to wearing apparel, but still using the Bureau of Standards horizontal test method.

2. *State Legislation.* A state law is in force in California. Pennsylvania introduced a bill last year

[2] Since this paper was written an additional half million dollar suit has been instituted, bringing the total pending litigation to two million dollars.

which in so many words stated nothing could be sold in the state in the way of textiles which burned more rapidly than 5 in. in 6 sec., no reference being made to test methods or how the material should be burned. Obviously, such a bill would be unworkable and it died in committee. We have been told by California officials that 24 states have shown interest in flammability legislation. This does not mean that bills have been introduced or that there would be any official knowledge of such bills in the various legislative bodies, but indications are that certain representatives and senators of these states have inquired concerning the California law, apparently with a view of instituting similar types of legislation in their own states.

3. *Test Methods.* Commercial Standard TS-4350 has not been accepted. Recent tests made in seven laboratories show fairly good correlation on some types of materials where other types show very poor correlation. In this series of tests 33 different fabrics were used, each laboratory analyzing a like portion of each fabric. Obviously, to have a successful test method we must be able to correlate in all types of fabrics, or else know the reason why. The Bureau of Standards machine has not been subjected to correlation tests and it is not known whether it will be possible to obtain correlation with this type of equipment. Hence, we have, at the present time, no accepted or proved test method.

4. In a study of conditions regarding accident from flammable fabrics, we have noticed a marked decline in the number of accidents, due in all probability to greater awareness of the problem which has been brought about by the large amount of publicity given this subject.

With conditions as they are today, the retailer is desirous of obtaining a good, workable Commercial Standard for the evaluation of flammable materials. He is willing that this standard be tried out on a voluntary basis to see whether or not it will solve the existing problem. However, should it fail on a voluntary basis, the retailer would then press strongly for Federal legislation. If, on the other hand, we find ourselves faced with numerous state laws on the subject of flammable textiles, the retailer would be forced to ask for National legislation and I am sure industry would agree with this viewpoint, for it would be very difficult, if not impossible, to operate where various states each have their own requirements.

In the event of undesirable Federal legislation being introduced, it would seem quite apparent that both retailers and manufacturers would then join hands and be sure that if any legislation is passed, it is of a sound nature and based upon sound, proven test methods.

A Stress-Strain Tester for Textiles Employing a Magnetic Strain Gage*

By J. W. Ballou[1]

SINCE the rate at which a physical test is performed has such a significant effect on measured textile physical properties, it is generally recognized that rigorous testing practice requires precise knowledge and adequate control of the testing rate. In the usual case, this means either the rate of elongation of the sample or the rate of application of load to the sample. The stress-strain tester described in the present paper is of the first type (that is, with controlled elongation rate) and was built as a primary instrument for use in a fundamental study of stress-strain relationships in yarns and filaments. In constructing such a device, the design is simplified considerably if one of the jaws holding the sample can remain virtually stationary throughout the testing cycle. This is obviously not possible with the usual pendulum-type stress recorder, but the strain gage, either electric or magnetic, can be used readily to fulfill this requirement. Since the strain gage is capable of measuring very small deflections, it may be used in conjunction with a stress beam or weighbar to form a stress-measuring system; that is, the upper jaw of a testing machine may be attached to the stress beam whose very small deflections, corresponding to relatively large loads, are easily measured by the strain gage attached to it. A suitable calibration permits converting the measured beam strains into corresponding stresses or tensions in the sample.

In the present application the magnetic strain gage was selected for use because it was commercially available from the General Electric Co., along with all the necessary additional equipment, and lent itself readily to use with a linear recording strip-chart potentiometer such as the Brown "Electronik." It has proved to be reliable and convenient in operation, provided certain precautions are taken and after experience in its use has been gained.

Figure 1 shows an over-all picture of the stress-strain tester. It can be broken down into two main components: an elongating mechanism consisting of a lower jaw attached to two threaded rods, which are traversed up and down by means of a motor-driven worm gear and threaded-nut drive; and the

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* Presented at the March, 1947, meeting of Committee D-13 on Textile Materials, held in New York, N. Y.

[1] Technical Division, E. I. du Pont de Nemours & Co., Inc., Rayon Dept., Buffalo, N. Y.

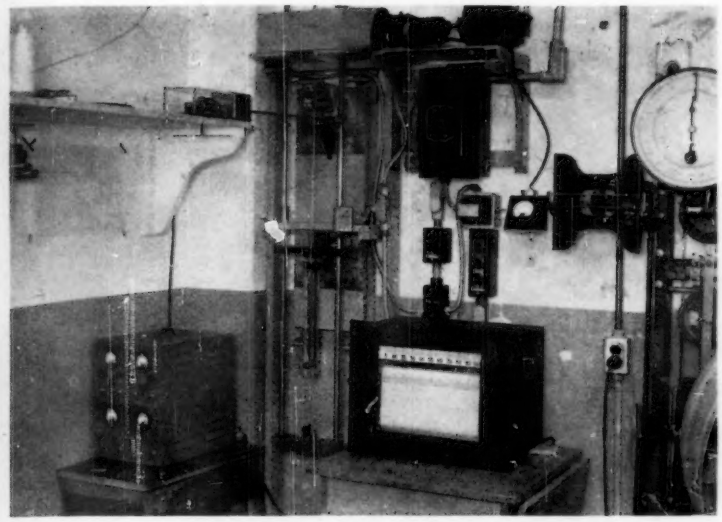

Fig. 1.—The Stress-Strain Tester.

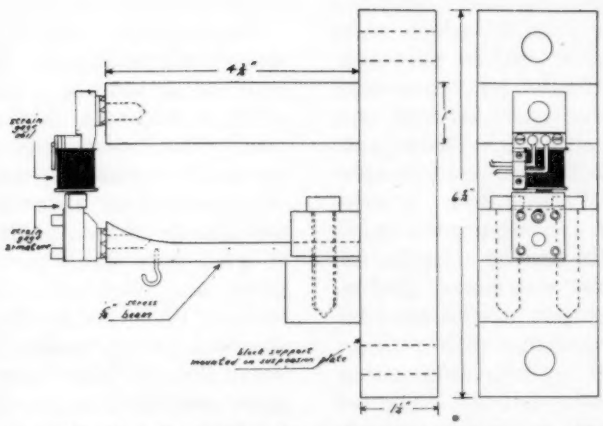

Fig. 2.—Working Strain Gage Mounting Showing Upper Jaw Hook.

stress measuring and recording equipment consisting of an upper jaw (actually merely a hook) attached to the stress beam, the strain gage, a comparison strain gage, a bridge circuit, amplifier, oscillator, power supply (the last four items contained in one unit), and a recording linear potentiometer. The recorder strip chart speed is adjustable but constant, and thus the chart displacement may be taken as a measure of elongation as the sample is elongated at a constant rate. Since the pen displacement records stress, it is seen that the recorder plots stress-strain curves.

The Magnetic Strain Gage

In principle, the magnetic strain gage, as applied to the stress-strain tester, works as follows: At the extreme free end of the stress beam is a steel armature in close proximity to the core of a small coil. This is shown diagrammatically in Fig. 2, with the corresponding photograph in Fig. 3. The coil forms one leg of a balanced a-c. bridge circuit. When the armature is pulled away from the core of the coil slightly, as a result of stress on the beam, the electrical characteristics of the coil are changed and the bridge balance disturbed. The resulting unbalance signal is amplified, rectified, and recorded as a measure of stress. Several beams are necessary to cover a good range of loads. All are about 4 in. long, $\frac{5}{8}$ in. wide, and of the following thicknesses in the vertical directions:

TABLE I.

Thickness, in.	Maximum Load, g.
1/16	300
3/16	300
5/16	2 000
7/16	5 000
15/32	10 000
9/32	

The normal gap between the core and armature is about 0.003 in. and is adjustable by means of an eccentric screw. Beams are interchanged with little difficulty, one coil serving for all.

A balancing or comparison strain gage forms one of the three remaining legs of the a-c. bridge. It is shown in Figs. 4 and 5. Referring to the diagram of Fig. 4, it is seen that the coil and armature are

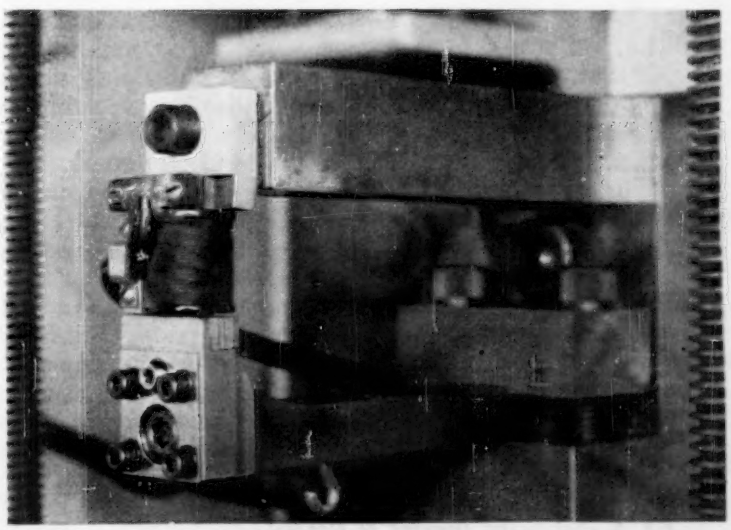

Fig. 3.—Working Gage and Stress Beam.

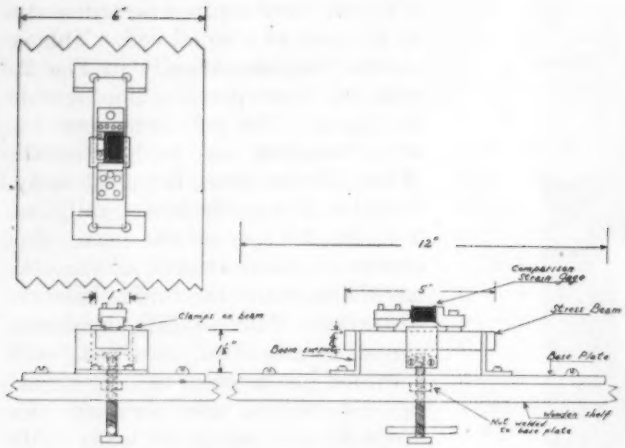

Fig. 4.—Comparison Strain Gage.

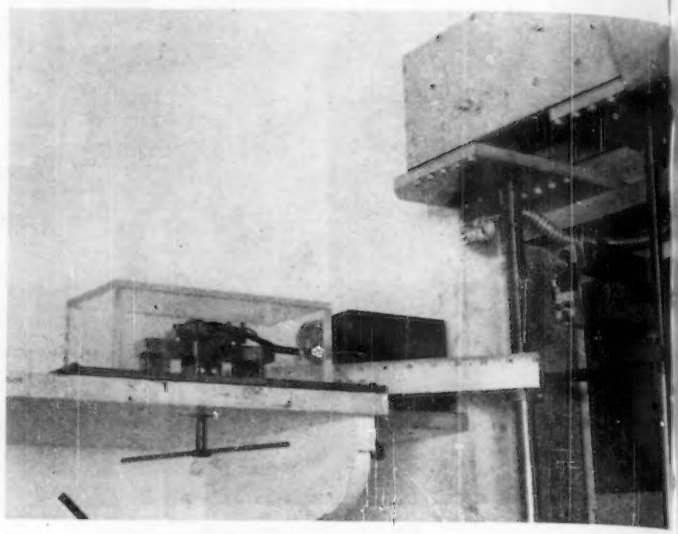

Fig. 5.—Comparison Strain Gage and Portion of Tester.

mounted on a beam which can be stressed by tightening a clamp attached to the center of the beam. This adjustment helps in the initial balancing of the bridge. Since the comparison gage is mounted near the working gage on the tester, drift and unsteadiness caused by local temperature variations are minimized. Both gages are housed in Lucite boxes to shield them from drafts.

The working gage and comparison gage together form the major items external to the "amplifier unit." This latter houses the remaining legs of the a-c. bridge, the 5000-cps. oscillator for energizing the bridge, an attenuator, amplifier, rectifier, and power supply. This is shown in Fig. 6. Any unbalance in the bridge caused by stressing the working gage shows up as an a-c. signal at the transformer. This is amplified and rectified and the resulting d-c. signal, which may be made proportional to the stress by proper selection of beams and amplifier (attenuator) settings, applied to the recorder. The adjustments "phase balance" and "amplitude balance" are used, in conjunction with the comparison gage, to balance the bridge initially for the condition of zero stress; that is, reduce the output to the recorder to a small value approaching zero.

Figure 7 shows the external wiring connections schematically. The resistance network between the amplifier unit and the Brown Recorder is necessary for matching purposes (to achieve linearity) and for sensitivity interpolation between attenuator steps. The constant voltage transformer helps the over-all stability of the system.

The amplifier unit and recorder are shown in Fig. 8. The former contains an extra amplifier channel which is not used in this application. The Brown "Electronik" Recorder has a full-scale sensitivity of 10 mv., and its strip chart has a useful scale of 11 in. Chart speeds of from $\frac{1}{2}$ to 2 in. per minute in steps are available. A General Electric Photoelectric Recorder has also been used in place of the Brown instrument at times when its higher chart speed of 6 in. per minute was desirable.

Other Details of the Stress-Strain Tester

The other major part of the tester is the sample elongating mechanism,

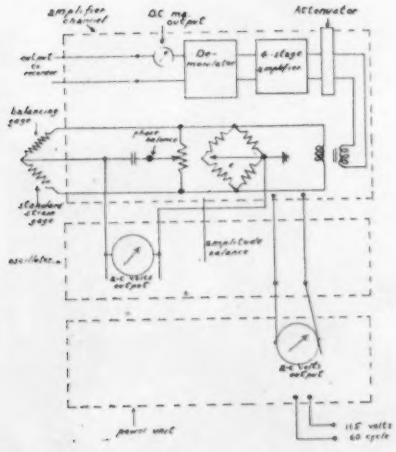

Fig. 6.—Schematic Drawing of General Electric Strain Gage Amplifier Unit.

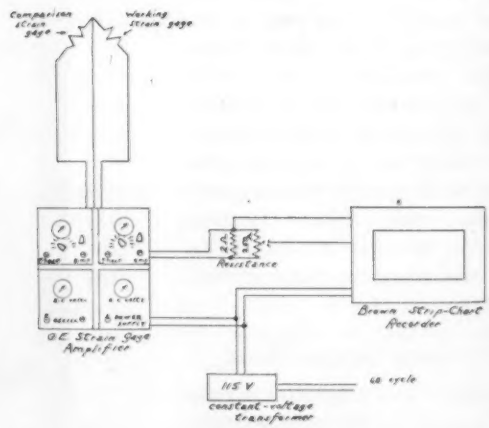

Fig. 7.—External Connections Between Strain Gage Components.

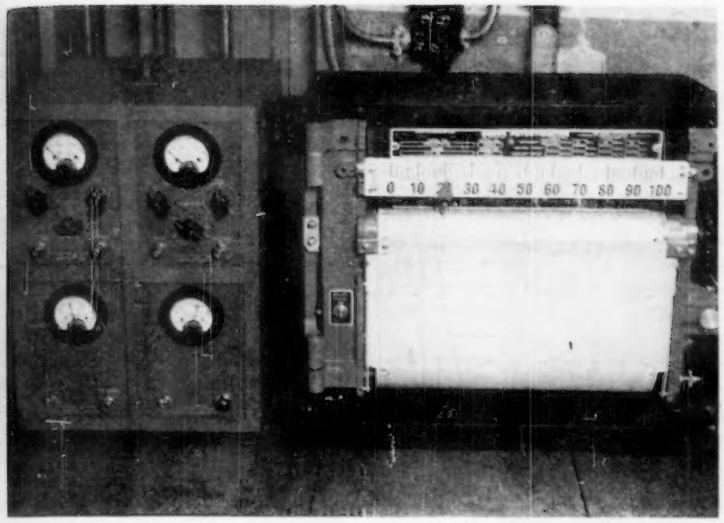

Fig. 8.—General Electric Amplifier Unit and Brown "Electronik" Recorder.

which is based on the use of a General Electric "Thy-mo-trol" drive. This is essentially a system of d-c. motor speed control making use of a rectifier circuit having two thyratron tubes for control of the motor armature current. In addition to starting, reversing, stopping, and controlling motor speed, the drive system provides overload protection, dynamic braking for stopping, etc. In the present application, a 230-v., $\frac{1}{3}$-hp. shunt-wound motor is used with the "Thy-mo-trol" to drive the sample elongating device. This latter can be seen by reference to Figs. 1 and 5. It consists of two vertical threaded shafts joined by horizontal crosspieces at both ends. This unit, that is, the shafts and connecting crosspieces, is traversed up and down by spiral gears with threaded holes through which the shafts ride. The spiral gears are contained in the box at the top of the tester and are driven by a worm drive from the motor, with a gear train interposed. Normally the speed of elongation ranges from 0.13 to 6 in. per minute; however, by gear changes this range may be increased to 0.04 to 18 in. per minute.

The lower crosspiece contains a sample clamp which comprises the lower jaw of the tester. However, an auxiliary crosspiece is provided with another clamp which is adjustable over the shaft length. This crosspiece, in addition, has provision for a 14-in. test tube with an internal sample clamp, suitable for wet tests. This is shown in place in Fig. 1.

Sample lengths (initial spacings between upper and lower jaws) may be anywhere from 1 to 50 in., thus providing elongation rates of from 0.08 to 1800 per cent per minute. Ordinarily 10 or 20-in. samples are used.

For convenience of operation, various interconnections between the motor controls and certain auxiliary apparatus are provided. Among the latter are limit switches to prevent over-run, to reverse automatically the mechanism at any elongation at the set speed, reverse it at its maximum speed for quick return to the initial sample length; and a timer for automatically stopping the drive for a fixed time interval before reversal. The necessity for this last item is discussed in the last section.

The control station for the "Thy-mo-trol" drive, as well as the timer and selector switches for selecting the type of limit switch control desired, can be seen in the center of Fig. 1. The indicator of a small generator-type tachometer is also shown. This is connected to the motor drive and is used in adjusting the elongation rate. The motor speed control is in the small box in the center of the picture. Two of the limit switches on one of the driven shafts are shown also.

The Operation of the Tester

To insure stable operation of the strain-gage system, the amplifier unit is left operating continuously when in daily use, since several hours' warm-up has been found necessary before stable operation is attained. No warm-up time is required for the recorder.

The question of linearity of response is an important one in the use of this instrument, and to obtain a straight-line relation between recorder deflection and applied load, a judicious selection of beam thickness and amplifier setting is required. Experience has provided suitable combinations usable for any given sample, however. Too thick a beam does not provide sufficient sensitivity, whereas too thin a beam will drive the pen off the chart or result in nonlinearity. In general, it is advisable to use a heavier beam with high amplification than a thinner beam with low amplification, since nonlinearity occurs when the armature-core gap becomes too large. With the beams given in Table I, it is possible to make full-scale deflection of the recorder correspond to from 5 to 10,000 g. This load range could be increased by using heavier stress beams. The required sensitivity (amplifier setting) for running a stress-strain curve for a given sample is determined experimentally; that is, after selection of a suitable beam, a load equal to the product of the approximate tenacity times twice the denier of the sample is put on the upper jaw and the amplification adjusted to give about three-quarters maximum recorder deflection. Twice the denier is used, since a loop of yarn is used around the upper jaw hook, providing two strands between the upper and lower jaws.

Frequent calibrations are made by hanging weights on the stress beam. If some nonlinearity shows up in the lower portion of the calibration, it is necessary to shift the initial zero stress position of the recorder pen to a slightly higher value by adjustment of the amplitude balance or the comparison strain gage beam.

Examples of Data Obtained

Figure 9 shows stress-strain curves obtained on a commercial 150-denier textile viscose yarn.

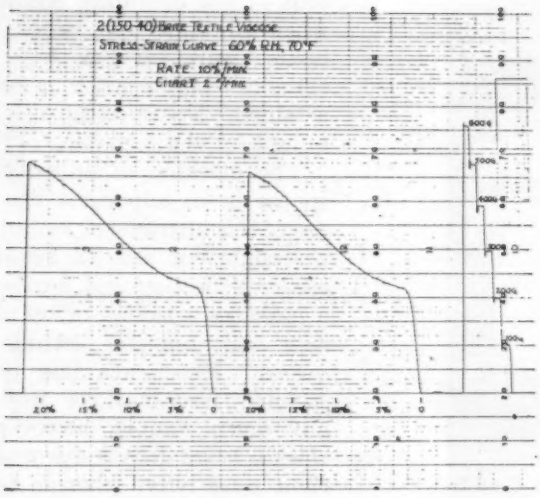

Fig. 9.—Stress-Strain Curves of Textile Viscose Yarn.

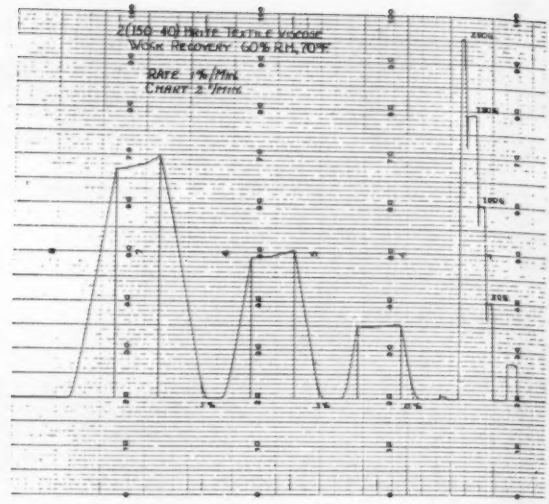

Fig. 10.—Work Recovery Curves of Textile Viscose Yarn.

Since the chart moves to the right, the strain axis goes from right to left. An elongation rate of 10 per cent per minute and a chart speed of 2 in. per minute were used. Thus 1 in. of chart travel corresponds to 5 per cent elongation and is so marked. The calibration is also shown. By plotting the calibration curve and picking off the breaking load, the tenacity in grams per denier may be obtained, since the effective denier is 150 × 2 (as the result of using a loop). A modulus of elasticity may also be obtained from the slope of the initial straight-line portion of the curve.

A series of work recovery determinations at different maximum extensions on the same material is shown in Fig. 10. The work recovery test is made as follows: Using an elongation rate of 1 per cent per minute, the sample is elongated to the approximate required extension, the elongating mechanism automatically stopped for 30 sec. and then reversed, and the return curve to zero stress obtained. The ratio of the area under the descending curve to the area under the ascending curve expressed in per cent is the work recovery, since this is the ratio of the work returned by the sample to the work put into the sample. In Fig. 10, remembering that the chart moves to the right, the work put into the sample is the area under the right-hand or ascending curve, and the work returned by the sample is the area under the left-hand or descending curve in each of the three cases shown. To determine the exact elongation, the initial straight portion of the ascending curve is extrapolated to zero stress to provide a starting point for measuring elongation. This takes care of the slight initial curvature introduced by crimp. The maximum elongations shown in Fig. 10 are 0.15, 0.3, and 0.5 per cent, respectively. The 30-sec. delay period at the middle of the cycle, during which some stress decay occurs, was introduced to conform to the procedure normally used in this laboratory with other equipment, although obviously other conventions may be used.

Acknowledgments:

The stress-strain tester described was designed by Messrs. M. T. O'Shaughnessy and H. E. Stanley. Subsequent evaluation of the instrument and development of test procedures was done by Mr. L. E. Amborski, who supplied the data shown. The author wishes to acknowledge the cooperation of the management of the Rayon Department, E. I. du Pont de Nemours & Co., Inc., in permitting this material to be assembled for publication.

Measurement and Elimination of Inertia Effects in Textile Testing Equipment by Means of Electric Strain Gages[1]

By Herbert F. Schiefer[2]

LARGE inertia forces may be exerted on specimens when they are tested for strength with current tension testing machines of either the pendulum or inclined plane type. These inertia forces arise from sudden changes in the velocity (acceleration) of the mass of the weighing systems. They are particularly pronounced at the beginning of a test, in repeated loading and unloading tests, in tear-resistance tests, in testing specimens of low extension, and in tests in which a sudden change in extension takes place.

Equations relating load to time, based upon simple theoretical considerations, show that the applied load is a periodic function for both pendulum and inclined plane testers. Experiments made on different materials confirmed the theoretical conclusions. In these experiments a resistance strain gage dynamometer was mounted in series with the test specimen.

This dynamometer, which consists of a shaft with a reduced section, is shown at A in Fig. 1, where it is attached to the upper clamp of a pendulum tension testing machine. Two resistance strain gages were attached to opposite sides of the reduced section to compensate for any bending of the shaft during a test and a similar unit was placed near the one in the machine to compensate for small changes in the ambient temperature of the constant temperature and humidity room. The electrical output which is a measure of the tensile load applied to the specimen, was amplified and recorded against time with a recording oscillograph.

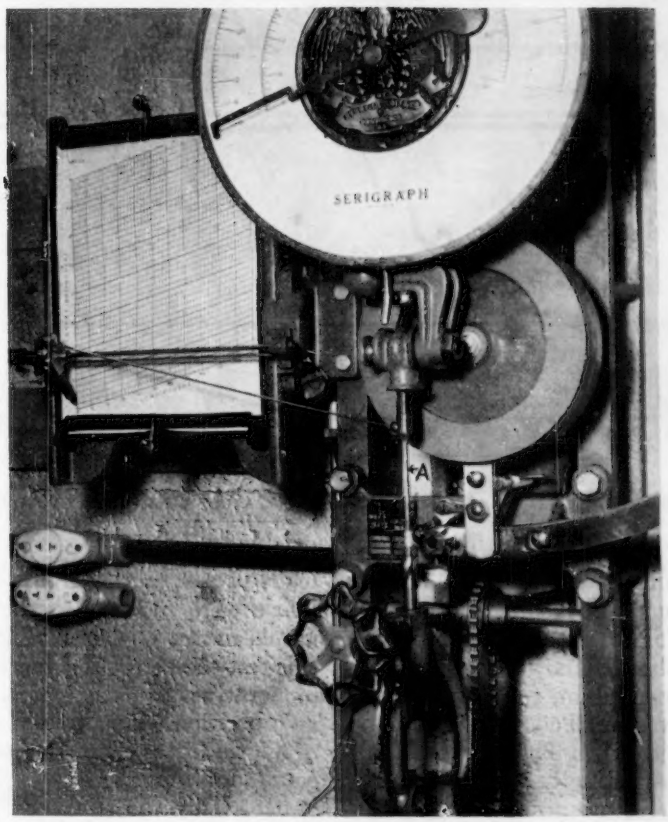

Fig. 1.—Pendulum Tester with Resistance Strain Gage Dynamometer Inserted Between Upper Clamp and Pendulum.

A typical oscillograph record of a strip tension test of a fabric is shown in Fig. 2. The applied load fluctuated greatly, owing to inertia forces, and the rate of loading varied enormously during the test. The variations in the inertia force and in the rate of loading with time are shown in Fig. 3. The periodicity was quite constant between 1 and 6 sec. It changed at about 6.2 sec., which is the time at which rupture started. During the region of actual rupture of the specimen, the velocity of the pendulum changed and inertia forces resulted as shown in Fig. 3. The applied loads in these experiments, as measured with the resistance strain gage dynamometer, differed considerably from the load indicated by the pendulum tester. At rupture, this difference depended upon the phase of the periodic inertia force and also upon the overthrow of the pendulum. The latter arises from the kinetic energy which the pendulum possesses at the instant of rupture.

A typical record of a tongue tear resistance test of a fabric specimen, which was obtained with a pendulum tester, is shown in Fig. 4. In this test the pawls of the pendulum were rendered inoperative during the test so that the pendulum was free to oscillate. When a tear ensued, for example at a load indicated by A_4 in Fig. 4, the pendulum swung back to some lower load, B_4. During this swinging back from load A_4 to B_4 the distance between the two clamps increased and the specimen tore across a number of threads. The load at these tears was not recorded. At load B_4 the motion of

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[1] Presented at the March, 1947, meeting of Committee D-13 on Textile Materials, held in New York, N. Y.

[2] Senior Physicist, National Bureau of Standards, Washington, D. C.

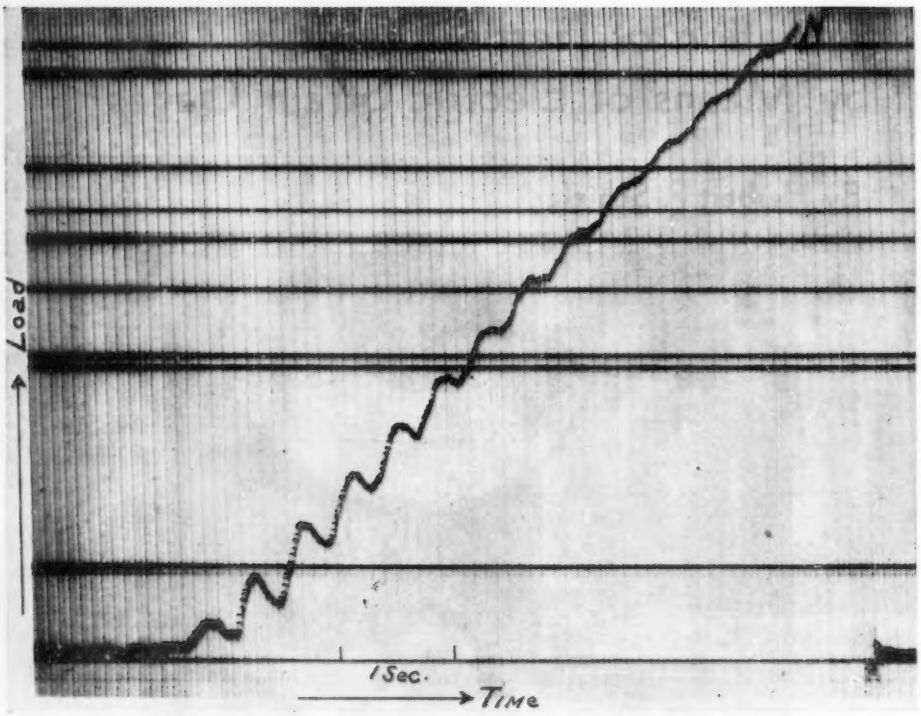

Fig. 2.—Oscillograph Record of a Strip Tension Test of a Fabric Made with a Pendulum Tester.

the pendulum was arrested and reversed and the recorded load increased from B_4 to A_5, where another tear resulted. The time required for the pendulum to swing from A_4 to B_4 was small compared to that from B_4 to A_5. The curve from B_4 to A_5 is distinctly wavy.

The oscillograph record which was made simultaneously with the record of Fig. 4 is shown in Fig. 5, and the corresponding points are shown by the same letters. The portion of the curve from B_4 to A_5 shows that the actual load fluctuated enormously, owing to inertia forces caused by reversing the motion of the pendulum at B_4. This portion of the curve, as well as the portions B_5 to A_6 and B_6 to A_7, could be represented very well by the equation

$$T = 1800 + 600t + 1000e^{-1.08t} \cos 4.25\pi t$$

where T is applied load in grams and t is time in seconds. The portions of the curve designated by A_3B_3, A_4B_4, A_5B_5, A_6B_6, and A_7B_7, where the specimen was actually being torn, clearly show that in each of these tears the tear was across a number of threads. The motion of the film in the recorder was too small, however, to resolve definitely the tearing loads of the individual threads. These individual tearing loads of a specimen from the same fabric were resolved in the oscillograph record shown in Fig. 6. In this test the pendulum was rendered inoperative by locking it at its zero position. This system was free of inertia forces, since the pendulum could not move, and the effect is indicated by the striking difference between the two records shown in Figs. 5 and 6.

Tension testing machines are being developed commercially by a number of concerns in which resistance or magnetic strain gages are incorporated to measure load. In some of these developments, the output of the strain gages is suitably amplified and recorded directly as a measure of the applied load. In others, the gages form one arm of a balanced Wheatstone bridge and the adjustment required, in this arm or in a second arm of the bridge, to maintain a balance is employed as a measure of the applied load. The former is preferable for making dynamic tests because high-frequency variations in load are followed faithfully. The latter is preferable for making strength tests according to current textile standards because greater stability is obtained.

The new tension testing machine being constructed for the Textiles Section of the National Bureau of Standards includes the following features:

1. Six capacities of 10, 20, 100, 200, 1000, and 2000 lb. are provided. A change in capacity to one higher or lower can be effected during a test by simply pressing a button on the control panel. The change is completed by a small motor in a few seconds. Thus the initial part of a test can be made and the results recorded with a low capacity and very high sensitivity.

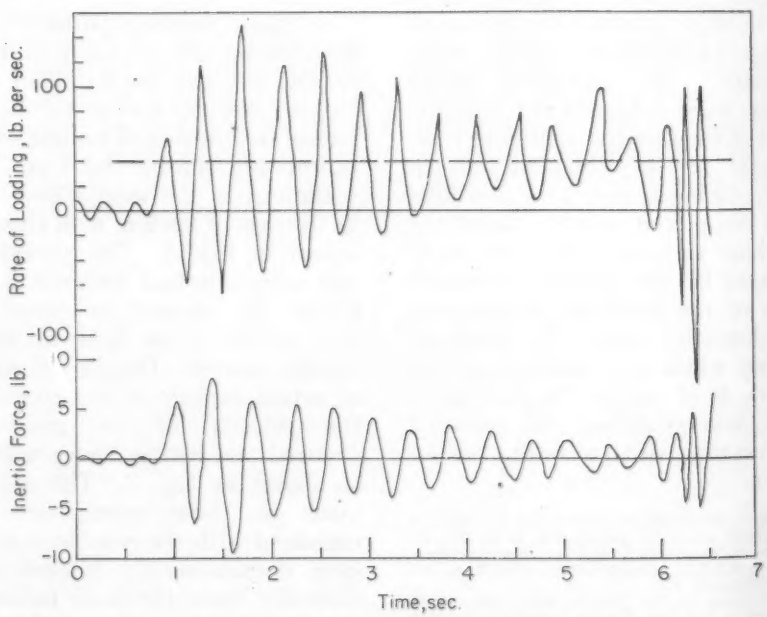

Fig. 3.—Curves Showing Variations in Inertia Force and in Rate of Loading During the Strip Tension Test of a Fabric.

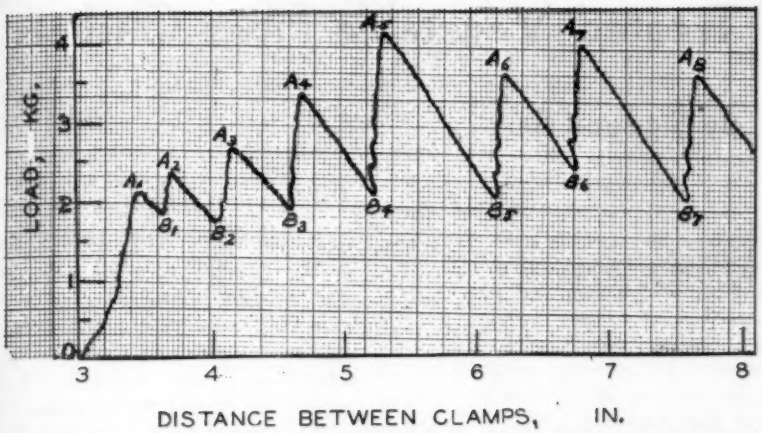

Fig. 4.—Record of a Tongue Tear Resistance Test of a Fabric Obtained with a Pendulum Tester.

The test can then be completed to rupture with a less sensitive and higher capacity as required. The load is measured and recorded electronically through a self-balancing inductance bridge. The applied load changes the inductance of an inductor, which is attached to the weighing beam. This inductor, which forms one arm of the bridge, is automatically adjusted to maintain a constant inductance. The adjustment required to maintain a balance is related to the applied load and is indicated directly on a dial or is recorded on a chart. The maximum deflection of the clamp attached to the weighing system is less than 0.002 in. for each capacity.

2. An internal extensometer is provided to record total extensions in the range from 0.5 to 10 in. with magnifications of 20, 10, 5, 2, and 1. A change in magnification can be accomplished by pressing the appropriate button on the control panel. The operation of this extensometer and the recording through a self-balancing resistance bridge is fully automatic through electronic controls. The movement of the clamp which is fastened to the weighing system, being less than 0.002 in., is negligible. The extension is therefore given by the motion of the other clamp. It moves the contact of a helical potentiometer that forms one arm of the resistance bridge. Any unbalanced current is amplified and operates a motor that adjusts the resistance in a second arm of the bridge to maintain the balance. The adjustment required to maintain the balance is related to the extension and is recorded directly with the desired magnification.

3. An external extensometer is provided to record the extensions in the range from 0.05 to 0.20 in. with magnifications of 200, 100, and 50. The operation of this extensometer and the recording through a self-balancing resistance-inductance bridge is also fully automatic through electronic controls. The extension with this extensometer is measured on gage lengths which can be adjusted to any value from 0.5 to 3 in. The extension in the selected gage length varies the inductance of an inductor that forms one arm of a resistance-inductance bridge. Any unbalanced current is amplified and operates a motor. It adjusts the inductance of a similar inductor that forms the second arm of the bridge to maintain the balance. The adjustment required to maintain a balance is related to the extension and is recorded directly with the desired magnification.

4. The machine can be operated at any constant rate of strain in the range of 0.05 to 20 in. per minute. Specimens of any length up to about 20 in. can be tested in tension or in compression.

5. An electronic circuit is also provided, controlled by the inductor attached to the weighing system, so that the machine can be operated at a variable rate of strain, within the speed limits of the "Thy-motrol" control motor, such that the rate of loading is any preassigned constant irrespective of the load-elongation characteristics of the specimen being tested.

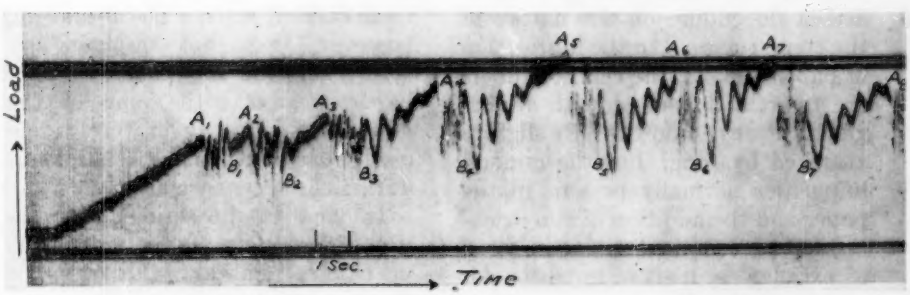

Fig. 5.—Oscillograph Record of the Tongue Tear Resistance Test of a Fabric Made with a Pendulum Tester.

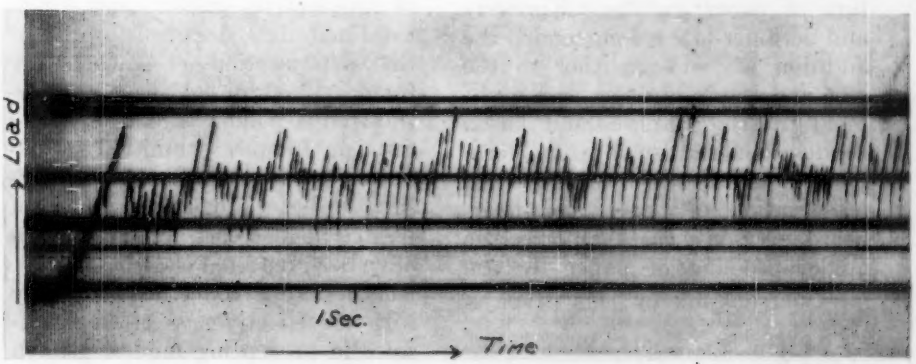

Fig. 6.—Oscillograph Record of a Tongue Tear Resistance Test of a Fabric in Which the Pendulum Was Rendered Inoperative by Locking It at Its Zero Position.

Fungus Resistance of Treated Vegetable Fiber Gaskets

By Sigmund Berk[1]

SYNOPSIS

The effectiveness against mold growth of vegetable fiber gaskets treated with six fungicides has been determined. For fungus proofing paper and vegetable fiber gaskets, 2 and 4 per cent copper pentachlorophenate, 3 per cent salicylanilide plus 10 per cent paraffin wax, and 0.4 per cent sodium pentachlorophenate gave complete protection against three species of fungi. However, the gasket material treated with 0.4 per cent sodium pentachlorophenate incorporated in the binder became saturated with moisture when incubated under conditions of high humidity. Zinc dimethyldithiocarbamate in concentrations of 2, 5, and 10 per cent gave partial to almost complete protection. With a vegetable fiber gasket material H, salicylanilide and dihydroxydichlorodiphenyl methane gave incomplete protection. No increased fungus resistance was imparted to the paper gaskets by incorporating salicylanilide, dihydroxydichlorodiphenyl methane, and sodium pentachlorophenate in the paper alone, in the impregnant alone, or in both the impregnant and the paper. In a cycled tropical humidity chamber, the gaskets treated with salicylanilide, dihydroxydichlorodiphenyl methane, and sodium pentachlorophenate were resistant to mold attack.

UNTREATED vegetable fiber gaskets are subject to attack by fungi when exposed in tropical areas or stored in temperate regions under favorable conditions of temperature and humidity. Paper composition gasket materials vary in their susceptibility to mold attack depending on the nature of the constituents. In the fabrication of paper gaskets, the cellulose fibers are fused and bonded with animal glues. Pure cellulose is only slightly attacked by fungi, but the mineral impurities normally present in the paper and the addition of starch sizing and protein binding agents serve as excellent sources of nutrition for mold growth. However, this source of food for fungi may be poisoned by the addition of fungicides to the animal glues used in the manufacture of paper gaskets. Kimberly and Scribner (7)[2] recommended the addition of beta-naphthol to the glue and starch in paper to prevent mold growth. Carswell and Nason (4) described the use of pentachlorophenol and its salts for the industrial preservation of paper and fiberboard. Nason *et al.* (8) reported the mildew-proofing of paper by the incorporation of sodium pentachlorophenate in the stock. Delmonte (6) cites the extensive work done by the Forest Products Laboratory on the mold resistance of protein glues treated with beta-naphthol, creosote, *o*-phenylphenol, and the chlorinated phenols and their sodium salts. The literature, however, does not disclose any studies on the mold resistance of paper treated with some of the newer fungicides which were widely used for tropicalizing equipment during the recent war.

In view of the serious degradation of cork, felt, and paper gaskets in tropical military theaters, the Society of Automotive Engineers sponsored a study committee, composed of representatives of various military services and manufacturers of automotive, gasket, and fungicidal materials, designed to prevent the deterioration of gaskets by fungi. Frankford Arsenal was authorized to conduct mold resistance tests on samples submitted by cooperating organizations. The results on the fungus resistance of treated bonded cork and felt gaskets have been reported elsewhere (1, 2). This report is concerned primarily with the effectiveness of six fungicides in preventing mildew growth on a number of types of vegetable fiber gasket materials.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] Chemist, Frankford Arsenal, Philadelphia, Pa.

[2] The boldface numbers in parentheses refer to the references appended to this paper.

METHOD OF TREATING GASKETS

Samples Nos. 84 to 106 (Table I), inclusive, were treated with fungicides by immersing the gasket strips for a few minutes in a bath containing the fungicides suspended or dissolved in water, ethanol, isopropanol, or Stoddard solvent. The treated gaskets were air dried at room temperature prior to exposure to the mold tests. Information on the percentage fungicide pickup by the various gasket materials is not available. However, results on the wet pickup obtained by immersing bonded cork strips in fungicidal solutions show (3) that the add-on varied from 17 to 38 per cent depending on the type of fungicide, solvent, or diluent used. In samples Nos. 119 to 136, inclusive (Table I), the fungicide was incorporated directly in the paper, in the impregnant, or in the binder used to fuse the cellulose fibers.

PROCEDURE USED IN TESTING FUNGUS RESISTANCE

Samples of untreated and treated vegetable fiber gasket materials were cut into strips approximately 1 by 3 in. Three methods of incubation were used. In test A, the paper gasket strip was suspended from the metal top of 1-qt. fruit jars containing ½ in. of water (1). Prior to inoculation, the gasket strip was wetted by immersing in distilled water. Inoculation was effected by dusting the lower portion of each strip with spores from one of the three test organisms used (*Aspergillus niger*, TC #215-4247; *Chaetomium globosum*, U.S.D.A. #1042.4; and a species of *Penicillium*, U.S.D.A. #1336.2). The inoculum was obtained by gently stroking with a camel's hair brush the sporulating surface of a pure culture of the fungus growing on mineral salts dextrose agar in Petri dishes. By screwing the metal top on the jar and storing at a temperature of 85 F. (29.4 C.), each container became an incubation cham-

TABLE I.—SUMMARY OF MOLD TESTS OF UNTREATED AND CHEMICALLY TREATED VEGETABLE FIBER GASKET MATERIALS.

Sample	Type of Vegetable Fiber Gasket	Fungicide or Chemical Protectant	Fungicide in Treating Bath, per cent	Test[a]	Test Organisms[b]			Cycled Tropical Humidity Chamber[b]	
					Aspergillus niger	*Chaetomium globosum*	*Penicillium sp.*	Exposure, weeks	Exent of Growth
No. 84...	Sheet Packing	Untreated	...	A	+	+	−		
				B	++++	++++	++++	N.T.	
No. 85...	Sheet Packing	Phenyl mercuric oleate	0.25	A	−	−	+		
				B	++	++	++	4	+++
No. 86...	Sheet Packing	Zinc dimethyldithiocarbamate	2.0	A	−	−	+		
				B	−	−	++	N.T.	
No. 87...	Sheet Packing	Copper pentachlorophenate	4.0	A	−	−	−		
				B	−	−	−	12	+++
No. 92...	Kraft	Untreated	...	A	++++	++++	++++		
				B	++++	++++	++++	N.T.	
No. 93...	Kraft	Zinc dimethyldithiocarbamate	1.0	A	+	−	+		
				B	++	+	++	4	+++
No. 94...	Kraft	Zinc dimethyldithiocarbamate	2.0	A	+	+	−		
				B	+	−	+	4	++++
No. 95...	Kraft	Zinc dimethyldithiocarbamate	5.0	A	−	−	+		
				B	−	N.T.	−	N.T.	
No. 96...	Kraft	Zinc dimethyldithiocarbamate	10.0	A	−	−	+		
				B	+	−	+	26	+
No. 100...	Kraft Paper	Copper pentachlorophenate	4.0	A	−	−	−		
				B	−	−	−	26	+++
No. 101...	Kraft Paper	Salicylanilide plus paraffin wax	3.0	A	−	−	−		
			10.0	B	−	−	−	26	−
No. 102...	Kraft Paper	Untreated	...	A	+	++	+		
				B	++	++	+	N.T.	
No. 103...	Manila Tag Paper	Untreated	...	A	+	−	−		
				B	++++	++++	++++	26	−
No. 104...	Manila Tag Paper	Zinc dimethyldithiocarbamate	1.0	A	+	−	−		
				B	++	+++	+++	N.T.	
No. 105...	Manila Tag Paper	Zinc dimethyldithiocarbamate	2.0	A	+	−	+		
				B	++	++	+++	26	−
No. 106...	Manila Tag Paper	Copper pentachlorophenate	4.0	A	−	−	−		
				B	−	−	−	26	−
No. 118...	V	Untreated	...	A	++++	++++	++++		
				B	++++	++++	++++	N.T.	
No. 119...	V	Sodium pentachlorophenate	0.4[c]	A	−	−	−		
				B	−	−	−	26	−
No. 122...	H	Salicylanilide to paper	4.0	A	+	+	+		
				B	++++	+++	++++	26	−
No. 123...	H	Salicylanilide to paper	2.0	A	+	−	+		
				B	+++	+++	++++	26	−
No. 124...	H	Salicylanilide to paper	1.0	A	+	+	+		
		Salicylanilide to impregnant	1.0	B	+++	+++	+++	26	−
No. 125...	H	Salicylanilide to paper	2.0	A	+	−	+		
		Salicylanilide to impregnant	1.0	B	+++	+++	+++	26	−
No. 126...	H	Salicylanilide to impregnant	4.0	A	+	+	+		
				B	++++	+++	++++	26	−
No. 127...	H	Dihydroxydichlorodiphenyl methane to paper	2.0	A	+	+	+		
				B	++++	+++	++++	26	+
No. 128...	H	Dihydroxydichlorodiphenyl methane to paper	4.0	A	+	+	+		
				B	+++	++++	++++	26	−
No. 129...	H	Dihydroxydichlorodiphenyl methane to impregnant	4.0	A	+	+	+		
				B	++++	++++	++++	26	−
No. 130...	H	Dihydroxydichlorodiphenyl methane to paper	1.0	A	+	+	+		
				B	+++	+++	++++		
		Dihydroxydichlorodiphenyl methane to impregnant	1.0						
No. 131...	H	Dihydroxydichlorodiphenyl methane to paper	2.0						
		Dihydroxydichlorodiphenyl methane to impregnant	2.0	A	+	+	+		
				B	+++	+++	++++	26	−
No. 132...	H	Sodium pentachlorophenate to paper	0.75	A	+	+	+		
				B	+++	++	+++	26	−
No. 133...	H	Sodium pentachlorophenate to paper	1.5	A	+	−	+		
				B	++	++	++	26	−
No. 134...	H	Sodium pentachlorophenate to impregnant	3.0	A	+	+	+		
				B	+++	+++	+++	26	−
No. 135...	H	Sodium pentachlorophenate to paper	0.75	A	+	−	−		
				B	+++	++	+++	26	−
		Sodium pentachlorophenate to impregnant	0.75						
No. 136...	H	Sodium pentachlorophenate to paper	1.5	A	+	−	−		
				B	++	++	++	26	−
		Sodium pentachlorophenate to impregnant	1.5						

[a] Test A—Inoculated samples incubated over water in Mason jars at a temperature of 85 F. Test B—Inoculated samples incubated in Petri dishes on solidified mineral salts dextrose agar at a temperature of 85 F. and above 80 per cent relative humidity.

[b] Code for Fungus Growth:
− = No Growth
+ = Slight Growth
++ = Moderate Growth Over Part of Sample
+++ = Moderate Growth Over Entire Sample
++++ = Heavy Growth Over Entire Sample
N.T. = Not Tested

[c] Fungicide incorporated in protein binder.

ber maintained at saturated moisture conditions. Although conditions of 100 per cent relative humidity are quite prevalent under tropical exposures, this test is somewhat more severe, since the jars approximate an environment of stagnant air saturated with moisture. This test has previously been reported (1, 3) as an accelerated test for cork gaskets.

In test B, the vegetable fiber gasket strip was placed on 20 ml. of sterilized and solidified mineral salts dextrose agar (NH_4NO_3, 3.0 g.; K_2HPO_4, 4.2 g.; $MgSO_4 \cdot 7H_2O$, 4.2 g.; dextrose, 5.0 g.; agar 15.0 g.; distilled water, 1000 ml.) contained in Petri plates. The sample was inoculated as in test A and incubated in a constant temperature room at 85 F. and a relative humidity above 80 per cent. This test shows the effectiveness of the fungicide treatments when the paper gaskets are incubated on a substratum that is an excellent source of food for mold growth.

Two to five replicates were used for each organism in both tests. After a 2-week incubation period, the vegetable fiber gaskets were examined and rated for extent of fungus attack.

The vegetable fiber gaskets were also exposed in a cycled tropical humidity chamber. The treated paper gaskets in duplicate were suspended by means of corrosion-

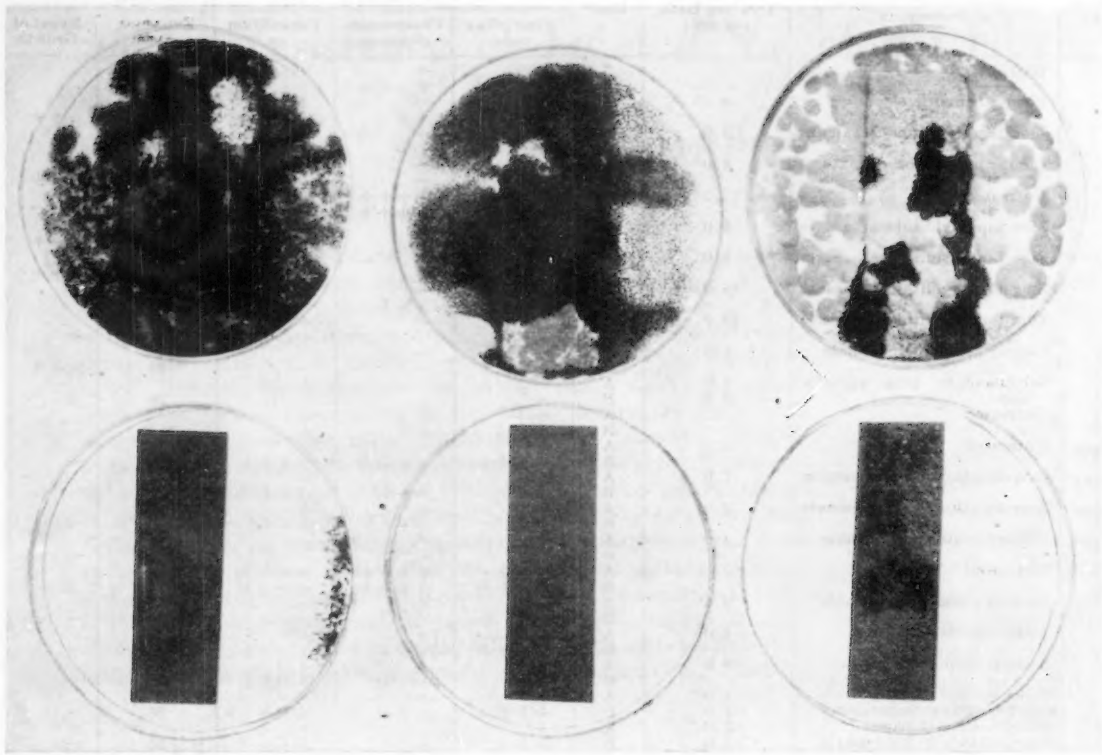

Fig. 1.—Mold Growth on Untreated Vegetable Fiber Gaskets Incubated on Mineral Salts Dextrose Agar in Petri Plates (Sample No. 118, Top Row), and Absence of Growth on Gaskets Treated with 0.4 per cent Sodium Pentachlorophenate (Sample No. 119, Bottom Row).

Treated specimens in bottom row show extensive leaching of the fungicide into the agar medium (test B) and wide zones of inhibition of fungus growth.

resistant wire from glass rods supported on shelves at the sides of the tropical room (Fig. 2). The atmosphere of this room was conditioned so as to simulate tropical conditions (3, 5) using the following cycle: For 16 hr. each day the temperature was held at 76 F. and the relative humidity at 95 to 98 per cent. During the remaining 8 hr., the temperature was raised to 85 F. and the relative humidity kept at 80 per cent. The paper gaskets were not inoculated since the normal fungus flora of the room was used as a source of inoculum.

Summary of Results

Table I shows the resistance to fungus growth of vegetable fiber gaskets treated with a number of fungicides. Complete protection to the gaskets against the three species of fungi in tests A and B was provided by the following fungicides: 2 and 4 per cent copper pentachlorophenate, 3 per cent salicylanilide plus 10 per cent paraffin wax, and 0.4 per cent sodium pentachlorophenate. Figure 1 illustrates the excellent protection provided by 0.4 per cent sodium pentachlorophenate incorporated in the binder in a vegetable fiber gasket material (sample No. 119), while the untreated controls were completely covered with a dense fungus growth. This gasketing material, however, has one disadvantage in that it becomes saturated with moisture when stored under conditions of high humidity. The great affinity for moisture is probably due to the nature of the protein binder used in the paper fiber gasket. Partial or almost complete protection was given to the gaskets by 2, 5, and 10 per cent zinc dimethyldithiocarbamate. There was very slight to no difference in the amount of protection obtained by varying the concentration from 2 to 10 per cent. The optimum concentration on kraft paper appears to be 5 per cent of zinc dimethyldithiocarbamate.

The absence or slight mold growth

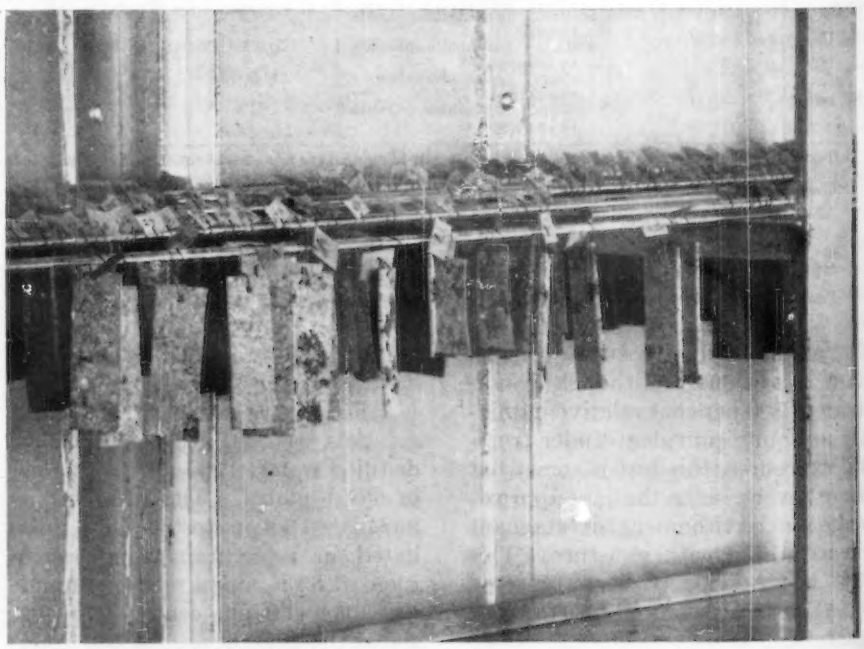

Fig. 2.—Mold Growth on Strips of Gasketing Material Suspended from Glass Rods on a Shelf in the Tropical Chamber.

shown by some of the untreated samples may be attributed to the presence of chemical preservatives which are added to the paper during the manufacturing process.

With vegetable fiber gasket material H (samples Nos. 122 to 136, inclusive, Table I), three fungicides—salicylanilide, dihydroxydichlorodiphenyl methane, and sodium pentachlorophenate—were incorporated in the paper alone, in the impregnant alone, and in both the impregnant and paper. None of these fungicide treatments offered complete mildew resistance against all three test organisms. There was no outstanding difference in the amount of fungus protection offered by the three methods of incorporating the fungicides. The most effective protectant for this material was 1.5 per cent sodium pentachlorophenate applied to both the paper and the impregnant. In all cases, incubating the inoculated treated paper gaskets H in fruit jars over water produced slight to no fungus growth. Incubating the samples on solidified mineral salts dextrose agar showed moderate to heavy growth. On the basis of test B, both salicylanilide and dihydroxydichlorodiphenyl methane are ineffective fungicides for this material.

Table I shows the results of the amount of mold growth on the vegetable fiber gaskets after 4 to 26 weeks of exposure in the cycled tropical room. There is a close correlation in the amount of mold growth shown by the samples incubated in the Mason jars (test A) and those exposed in the tropical room. However, the sheet packing material treated with phenyl mercuric oleate and copper pentachlorophenate and the kraft treated with 1 and 2 per cent zinc dimethyldithiocarbamate and copper pentachlorophenate had increased susceptibility to mold growth in the tropical room. The increased susceptibility to fungus growth of some fungicidally treated materials when exposed in the tropical chamber may be attributed to the loss of the fungicide due to: (*a*) volatilization, since the air in the room is constantly circulated while in the Mason jars exposure the air is stagnant; (*b*) aqueous leaching of the fungicide from the treated material following the periodic condensations of moisture on the material during the change in the temperature and relative humidity cycle. The most effective fungicides in the tropical room were: salicylanilide, dihydroxydichlorodiphenyl methane, and sodium pentachlorophenate.

On the basis of the three types of exposure, complete protection to vegetable fiber gaskets was provided by 3 per cent salicylanilide plus paraffin wax, 0.4 per cent sodium pentachlorophenate, and 4 per cent copper pentachlorophenate.

Acknowledgments:

Appreciation is expressed to the Ordnance Department for permission to publish this paper. The author wishes to acknowledge the cooperation of the Ordnance Laboratory Division of Frankford Arsenal, in particular C. C. Fawcett, E. R. Rechel, M. Frager, L. Teitell, and the members of the photographic section.

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Discussion of Paper on Measurement of Metal Polish Performance[1]

MR. V. M. MANTZ.[2]—Over the years we have made a considerable amount of Navy polish, and I think we are in a position to judge the merits of this very well written article. In our opinion it covers the subject very thoroughly and presents a good practical specification.

There are a few points I should like to discuss. The hardness of the brass or the type of brass used in making the disk should be carefully specified, as there is a possibility of wide variation in the abrasion number, if this is not done. Another point in question is the type of billiard cloth used. Perhaps some specification on the cloth should be included.

We have noted that the rubber headpiece wears rather unevenly and should be replaced whenever any uneven condition develops. We have noted that even though the rubber piece we use is rather soft, it becomes uneven and tends to give erratic results. On the Caking Number Test, in which the material is centrifuged, a gentle inversion is stipulated. Some inspectors may give it a rather hard shake on turning over and then, others may turn it over very carefully, which would make some difference in the number of inversions necessary to disperse the solid material, and consequently a difference in the Caking Number.

It was also brought up by our control man that there should be a better application of the polish sample to the specimen, but I personally think that this point is well covered in the article and that there is sufficient polish used to allow for any losses in the polishing operation.

Our metal polish has fully passed all previous specifications. The present article presents the best parts of all previous specifications and is a combination of all the specifications. We should like to congratulate Messrs. Clarke and Adams on the article.

MESSRS. ADRIEN S. DUBOIS[3] AND J. G. SINSHEIMER.[3]—The presenta-

[1] Frank E. Clarke and Robert C. Adams, "Measurement of Metal Polish Performance," A.S.T.M. BULLETIN, No. 147, August, 1947, p. 57.
[2] Director of Research, R. M. Hollingshead Corp., Camden, N. J.
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tion of the paper by Clarke and Adams coincided with research work being carried out in our laboratories. The timeliness and inherent usefulness of the authors' approach to the problem prompted us to present a few comments based upon our work with the methods described in this paper as well as in Navy specification 51P5f.

All our tests were obtained on four different polishes, two of which are commercial products, while the others were in the development stage.

Stability Test:

With the four polishes tested, centrifugation at 320 rpm. did not lead to any appreciable change in the products. In view of this, the speed was increased gradually up to 1280 rpm. Optimum results were obtained at 960 rpm. At this speed the four polishes could be differentiated, while this was not possible at higher or lower speeds. The results are summarized in the accompanying Table I.

TABLE I.

Polish	Speed of Centrifugation, rpm.			
	320	640	960	1280
A (separated)	N	SS	S	P
A (not separated)	N	SS	S	P
B	N	SS	SS	P
C	N	N	SS	P
D	N	S	P	P

N = no settling; SS = slight settling; S = definite settling; P = abrasive packed at bottom.

Difficulties were encountered in the determination of the caking numbers. Apparently the behavior of the polish in this test is greatly influenced by its viscosity, and polishes having a high viscosity could not be evaluated by this procedure. In such cases, probing with a rod, although only qualitative, was more feasible.

It happened that several lots of an experimental polish had been standing on the shelves for up to six months. A number of these had separated into a clear, aqueous layer and a sediment consisting of abrasive. These lots, after shaking to make them homogeneous, were investigated by the same procedure, but no difference could be detected between these and the samples which had not separated on standing. Obviously, this test does not allow for determining stability against this type of separation. The commercial importance of this feature points to the need for a more comprehensive test.

Abrasion Test:

This test has given very satisfactory results. It seems, however, that an increase in the number of revolutions and drying of the disk to constant weight would reduce errors in weighing to a minimum and thus ensure more closely reproducible results.

FRANK E. CLARKE (*author's closure by letter*).—The authors wish to thank Messrs. Mantz, DuBois, and Sinsheimer for their constructive comments and suggestions regarding this paper.

The observations concerning the desirability of standardizing test specimens are in order. The composition and hardness of the metal specimens are important despite the fact that the related Navy specifications for polish contain practically no limits for these characteristics. In this investigation of metal polish performance, the polish test panels were made of 70–30, cold-rolled, yellow spring brass with a Rockwell B hardness of 90.5 to 91.5 while the abrasion disk was Muntz metal (60–40) with a Rockwell B hardness of 65. Cold-rolled, sterling silver with a Rockwell B hardness of 35–45 was used for both the polish test specimens and the abrasion disk in the evaluation of liquid silver polish. An investigation of the practicability of spring brass for all specimens used in testing brass polish is now under way. The specification of cold-rolled, sterling silver specimens is considered adequate insurance of uniformity of results in testing liquid silver polish. We have observed no variations in abrasive-number determinations attributable to variations among batches of billiard cloth obtained under the applicable specification.

The rubber head of the polishing machine described in this paper shows no evidence of wear of the type mentioned by Mr. Mantz despite the fact that the head has worn a groove approximately $\frac{1}{16}$ in. into the brass polish table. It is possible that ours is a better grade of rubber than that used by Mr. Mantz. It is first grade, black, prewar rubber.

We agree with Mr. Mantz's suggestion that the term "gentle inversion" in the caking test is liable to misinterpretation. It is intended that the bottle be slowly turned upside down without shaking it. If the operation is performed too vigorously, the caking number may be reduced appreciably. This difficulty could be eliminated by providing a simple mechanical device for inverting the bottles without introducing the human element.

The caking studies described by Messrs. DuBois and Sinsheimer appear to be unnecessarily definitive for the intended purpose. The caking test under consideration was included in the polish specification simply to insure against the acceptance of polishes with intolerable caking tendencies and is not intended to discriminate among polishes with similar, acceptable caking tendencies. When applied in development tests to various polishes of known caking tendencies, the specified test yielded the desired order of differentiation. The observation that polishes of higher viscosity do not tend to form definite cakes on centrifuging is correct. Heavy emulsions frequently yield caking numbers of one or two which agrees with the fact that they do not form persistent abrasive cakes during storage. Such consistency is more common to liquid silver polish than to brass polish. Incidentally, it should be noted that separation of polish abrasive during storage is only objectionable if the cake does not redisperse quickly on shaking.

The suggestions of Messrs. DuBois and Sinsheimer concerning the abrasion test also appear to be based on the assumption that the test is intended to measure small differences between polishes of similar abrasive characteristics. This is not the case. In the brass polish and silver polish specifications the maximum abrasive numbers of 40 and 20 mg., respectively, are large enough to be determined accurately with an analytical balance. Accordingly, longer periods of rotation cannot be justified for inspection tests. On weights of this magnitude, oven drying to constant weight should not provide a significant increase in accuracy over careful drying with a paper towel or chamois.

Some Fundamentals of Glass Adhesion

By Frank Moser[1]

ADHESIVES have developed largely by empirical methods and through the years "cut and try" procedures were used for the joining of materials. Adhesive formulation was considered an art rather than a scientific endeavor which relied upon the basic principles of chemistry and physics. During the last decade adhesives have become important for bonding together a wide variety of materials as wood, metals, rubber, glass, paper, and plastics.

With the development of synthetic resins a new interest was created in the fundamentals of adhesion, as such basic information undoubtedly will be necessary for the improvement of adhesive formulations. The nature of adhesion has long been a controversial subject and the present consensus appears to favor "specific attractions" as a basis for a theory of adhesion. However no one factor is considered responsible, but basic principles of chemistry and physics are involved in the surface attractions of materials. As no satisfactory explanation has been established, exploratory studies were initiated and correlation attempted between certain fundamentals and bond strength of adhesive assemblies. A complete literature review of adhesives and adhesive action is not presented in this paper, but reference is made to previously published summaries by Rinker and Kline (17),[2] McBain, *et al.*, (15), Weyl (20), and de Bruyne (6).

Theories of Adhesion

Early postulations described adhesion either as a mechanical process which relied upon solidification of the adhesive in the pores of the material or as a specific attraction which was dependent upon chemical and physical forces. The present tendency is to perpetuate the "specific" theory of adhesion, and even in the gluing of woods, certain evidence (2) points to the fact that basic forces are involved. No definite mechanisms have been found for things sticking together, but the numerous postulations that have been offered associated the adhesion phenomenon with certain chemical and physical forces such as molecular and atomic attractions, polarity of surfaces, orientation dispersion and induction effects of molecules, and the functional or end groups of organic compounds used in adhesive formulations. Also, adhesion may be attributed to electrostatic, covalent and metallic forces of the primary valence type or to secondary or van der Waal's forces. Experimentally, these attractions are difficult to determine, as well as to obtain, finite values. However, bonding energies have been calculated by Pauling (16); and Lennard-Jones (14) has approximated the electrostatic attractions between surfaces and charged particles.

The effectiveness of primary valence bonds has been demonstrated by Gurney (10) in the use of brass plating techniques for joining rubber to metal. Adhesion was secured through sulfur bridges established by copper sulfide formation. Another instance of chemical bridging was cited by Campbell (3). In bonding woods, hydrogen bridges were assumed as being responsible as a monomolecular film of water attaches the cellulose structure to the protein molecule of the glue, whereas hydrogen bridging is active in bonding cellulose chain units in intramolecular attractions.

A chemical bonding theory is suggested by Weyl (20) which he designates as a continuation of the glass structure, for example, stannic or titanium oxide coatings on glass surfaces. However, other forces may be responsible and where no chemical linkage is possible the adhesion is due to the formation of an intermediate layer as an oxide film or to the formation of a highly polarizable ion on the glass surface. In accounting for adhesion of the high polymeric materials, such as polyvinyl butyral in safety glass, Weyl states that the van der Waal's forces as well as induction, orientation, and dispersion forces of molecules are involved.

De Bruyne (6) states that the majority of adhesives depend upon the secondary forces as induction, orientation, and dispersion; but as the induction forces are usually negligible, the orientation and dispersion effects predominate in securing the attraction of surfaces by means of the adhesive molecules. In predicting adhesion de Bruyne (7) theorizes that nonpolar as well as polar materials are held together by attractive forces, but as the polar forces are usually stronger than the nonpolar the tendency is to squeeze the weaker molecules from the mixture which often results in having incompatibility of materials and lack of adhesion between polar and nonpolar substances. Thus, in order to secure adhesion nonpolar adhesives must be used in connection with nonpolar materials, and polar adhesives for polar compounds.

Del Monte (8) in reviewing the theories of adhesion divided the influences into physical and chemical factors and suggested that the surface properties of the materials are of primary importance. The physical forces included surface tension, contact angle, and viscosity, whereas wetting of the solid surface is influenced by these physical properties and also by the condition of the solid. Surfaces are usually contaminated either with oxide films or with thin layers of gas and moisture which will naturally reduce surface energy and adhesion if the surfaces are not properly cleaned before bonding. The chemical factors that were suggested as having a bearing on adhesion were the po-

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[2] The boldface numbers in parentheses refer to the references appended to this paper.

Fig. 1.—Glass Tension Specimen and Fixtures for Testing Glass Adhesive Under Tension Loading.

larity of the adhesive, orientation force of the molecule, and the end or functional group.

The importance of functional groups of molecules has been investigated by Selden and Prutton (18, 19) for the adherence of paint films. An adsorption method was used for determining residual valence forces in connection with certain resins and plasticizers. The results indicated that the presence of a —COOH group increased adhesion, but if the group was replaced with sodium or by esterification the adhesion was markedly decreased. Doolittle and Powell (10), in copolymerizing monomeric vinyl acetate and vinyl chloride in presence of a small amount of malic acid, obtained a marked improvement in adhesion, but if too high proportions of the carboxyl group were present, or if the carboxyl group was neutralized with a hydroxide the initial adhesion was destroyed.

Others (1, 6) have stressed the importance of wetting as one of the requisites of good adhesion. Also, the angle of contact, the surface tension, and the cohesive force of the adhesive play important roles in wetting and in the affinity that the solid has for the adhesive. Rinker and Kline (17) contend that the attraction of solid for liquids which form the zero contact angle is more important than the wetting angle, whereas Bikerman (1) maintains that the primary functions of the adhesive are to displace the adsorbed gases, wet the surface, and form a zero angle of contact between the adherent and the adhesive. De Bruyne (6) states that a zero angle of contact between two members and the adhesive is indicative of good adhesion.

An appraisal of the suggested theories responsible for adhesion suggests that adhesion may be a result of a multiplicity of factors which may be difficult to evaluate experimentally by a direct approach. Thus, in the following exploratory studies correlations were attempted between various properties and the tensile strength of bonded glass assemblies.

Experimental Results

Apparatus and Methods:

Glass adhesion presents a more difficult problem than the adhesion of other materials as the test specimens must be machined to size before cementing, and due to the smooth surface the standard serrated grips of testing machines will not hold the glass without breakage or slippage. Consequently, a special steel grip was constructed so as to apply the load on the flat glass surface during the evaluation of the tensile strength. Heat-tempered glass, "Herculite," was used to reduce fracture and to promote failure in the adhesive. The type of grips and the tension specimens are shown in Figs. 1 and 2.

The glass specimen is similar to the Tentative Method of Test for Tensile Properties of Adhesives (D 897–46 T)[3] except that the glass specimen is made by bonding three pieces of glass together where one sideof a 1½-in. square of "Herculite" is adhered to both sides of a 1-in. square. The bond strength recorded was the average of ten replicated tests. An alternate type of specimen is the cross-lap tension test, which is made by cementing a

[3] 1946 Book of A.S.T.M. Standards, Part IIIB, p. 1217.

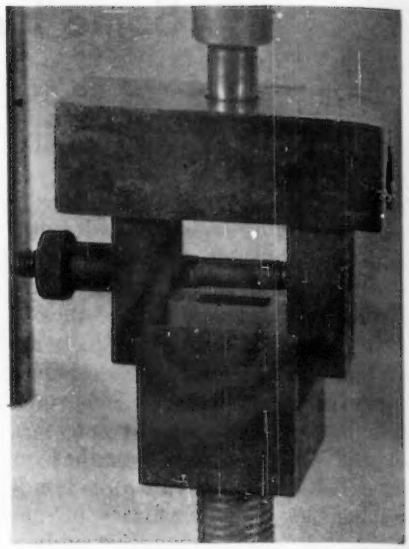

Fig. 2.—The Cross-Lap Specimen, and Fixtures for Testing Bond Strength of Adhesives.

1 by 1½-in. piece at right angles to another 1 by 1½-in. piece giving a 1 sq. in. bonded area.

Surface tension of the liquid adhesives was determined by the ring method using a Cenco No. 70540 interfacial tensiometer. A modification of the contact angle method described by Langmuir (13) was constructed. The modification consisted of mounting the point source of light on a lever arm above a tilting plate for holding the sample. Appropriate protractors on the plate and lever arm aided in measuring the angle when the star of incidence just disappeared from the droplet.

Physical Properties and Bond Strength of Adhesion:

Data for contact angles, surface tension, and tensile strength of adhesive bonds between glass are given in Table I and include the type of adhesives which give good adhesion, as well as the ones that had little or no adhesion to glass surfaces. The contact angle measurements gave static angles varying from 43 to 3 deg., whereas the advancing angle varied from 18 to 0 deg. The vinyl acetate and the alkyd types had almost a zero angle of contact, indicating good wetting and spreading qualities. The modified phenolics or vinyl-phenol combinations had relatively lower advancing angles of contact, whereas the pure phenol-aldehyde

TABLE I.—CONTACT ANGLE, SURFACE TENSION, AND BOND STRENGTH BETWEEN GLASS SURFACES FOR VARIOUS TYPES OF ADHESIVES.

Sample	Type of Adhesive	Contact Angle		Surface Tension, dynes per cm.	Bond Strength, psi.
		Static Angle, deg.	Advancing Angle, deg.		
No. 1....	Modified phenol	15	7	31.6	1580
No. 2....	Modified phenol	15	6	32.7	1170
No. 3....	Phenol-aldehyde	25	18	54.0	10
No. 4....	Phenol-butyral	25	7	37.8	1650
No. 5....	Vinyl-phenol	12	7	31.0	1540
No. 6....	Buna N-phenol	12	6	29.0	1200
No. 7....	Polyvinyl-acetate	13	2	32.5	660
No. 8....	Cellulose nitrate, vinyl	20	7	35.0	790
No. 9....	Buna N resin-base	35	18	41.3	1500
No. 10....	Rubber base	15	5	43.1	200
No. 11....	Acrylic acid	6	2	32.7	510
No. 12....	Alkyd	3	0	41.8	200
No. 13....	Resorcinol	37	12	45.7	10
No. 14....	Furan	38	12	48.7	10

resin maintained a higher angle of contact, 18 deg. The Buna N adhesive had almost as high an advancing angle of contact as the phenol-aldehyde, but in this case the adhesive had a fairly high solid content and a rapid volatilizing solvent which complicated the measurement by a skin formation over the surface of the adhesive droplet and may have been responsible for the lack of wetting. In the case of the phenol-aldehyde, the lack of wetting probably was influenced by the higher viscosity and higher surface tension. In examining the bond strength in relation to contact angles and surface tension, some correlation exists between these factors, a high surface tension coupled with a large angle of contact indicates poor adhesion, while a small angle of contact together with a low surface tension of the liquid adhesive usually gives a higher adhesion value. Although there appears to be some correlation between wetting and adhesion, the contact angle at room temperature may be only one of many factors responsible for obtaining adherence. Also, in the case of the heat-cured or heat-activated type of adhesives the contact angle approaches zero when heated to the flowing temperature. This was the case with the Buna S resin-based adhesive, the vinyl acetate, the nitrocellulose-vinyl combination, and the thermoplastic modified phenolics, as a zero angle of contact was found when examining these adhesives at elevated temperatures. The Langmuir method does not appear applicable for adhesives having volatile solvents, as the results are undoubtedly influenced by the rapid skin formation. Thus, studies are under way to check the above results using Kellogg's (11) captive bubble method where volatilization of solvents may be controlled while making the determination.

The high surface tension, 54 dynes per cm in the case of the pure phenol-aldehyde, indicates that a high cohesive force of the adhesive molecule may be associated with the low adhesion value. Wetting appears to be an important requisite for securing adhesion. Surfaces, such as glass and metal, which are easily contaminated by the atmosphere or other environmental conditions, usually have thin films of gases, grease, or moisture vapors on their surfaces. For example, if a plate of glass is held in a flame, the moisture is rapidly driven from the surface. The glass surface may be treated to render it hydrophobic, as in the case where chlorosilane vapors are forced on the moist surface. If the treated glass surfaces are then bonded with a modified phenolic adhesive, very little adhesion is secured. Such treatment rendered the surface hydrophobic and reduced the interfacial attraction, giving a higher contact angle and poor adhesion.

The effect of surface preparation on bonding strength was investigated for glass surfaces using a modified phenolic, and a phenolic-butyral adhesive. Table II gives tensile strength values obtained under the varied conditions for the two adhesives. The fire polishing, pumice and water treatment gave the lower value for the phenolic, while the same two treatments were low for the phenol-butyral combination. Cleaning with acetone appeared almost as effective as the chemical treatments, thus indicating that any treatment which insures good wetting appears desirable. In such cases as where the cleaning material may be adsorbed on the surface, as pumice or chromium, adhesion is partially between the adsorbed material and the adhesive resulting in lower adhesive strength. This influence was demonstrated in bonding an anodized aluminum bracket to a glass mirror using an alkyd type adhesive. Adhesion failure was very prevalent when the adhesive was applied directly to the anodized surface, but if the anodizing material was removed and the adhesive applied directly to the pure aluminum surface, adhesion was sufficient to cause glass fail-

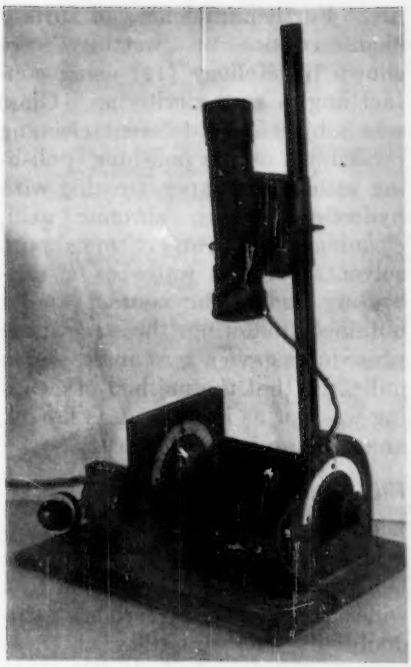

Fig. 3.—Apparatus for Measuring Contact Angles.

TABLE II.—METHODS OF CLEANING GLASS SURFACE IN RELATION TO BOND STRENGTH.

Method of Cleaning Glass Surface	Tensile Strength of Adhesive Bond	
	Modified Phenolic, psi.	Phenol-butyral, psi.
Wiped with dry clean cloth	1050	740
Cleaned with c. p. acetone	1100	1490
Fire polished by holding in open flame	875	850
Immersion in concentrated HCl, rinsed and dried	1100	1050
Immersion in 25 per cent NaOH, rinsed and dried	1010	1360
Chromic acid cleaning solution, rinsed and dried	950	1560
Pumice and water, rinsed and dried	810	800

ure. Further influences of surface characteristics on wetting were shown by Kellogg (12) using contact angles as the criterion. Glass was subjected to different cleaning procedures as fire polishing, polishing with emery paper, treating with hydrofluoric acid, chromic acid, cleaning solution, and chemical pure solvents. Using water as a calibrating agent, the contact angles obtained following these cleaning procedures gave a zero angle, which indicated that the method of cleaning was not as important as having an uncontaminated surface.

Functional Group and Adhesion:

In the new developments in adhesive formulations, attempts are being made to secure adhesion to a wide variety of materials. Undoubtedly the versatility of these newer adhesives is being attained by having proper functional groups incorporated to insure compatibility. According to de Bruyne (6), the orientation of the molecule may be the necessary requisite for securing a good bond. For example, gelatin and glue are amphoteric materials, and their functional groups are orientated with respect to the surrounding media, which in turn alters the active end group of the molecule. Primer coats have been very effective for changing compatibility between the adhesive and the surfaces. This is essentially an orientation phenomenon whereby the primer constituents are linked with the respective surface to exposed polar or nonpolar groups. An example of this type of reaction was encountered in adhering butyl rubber to glass. Almost any formulation which had an affinity for the butyl rubber failed to give permanent adhesion to the glass unless a specially prepared primer (a colloidal silicate-phenolic combination) was applied to the glass surface before applying the adhesive for bonding the two materials. Inasmuch as the primer was made up of a colloidal silicate and a phenolic constituent, an orientation of the molecule undoubtedly occurred where the colloidal silicate was attached to the silicon-oxygen network, whereas the phenolic radical was exposed at the surface of the primer film. Consequently, increased adhesion was secured due to a change in compatibility by the exposed functional group.

TABLE III.—COMPARISON OF BOND STRENGTH OF ADHESIVE BETWEEN GLASS SURFACES WITH AND WITHOUT A PRIMER COST.

Type of Adhesive	Bond Strength Under Tensile Loading, psi.	
	Herculite Glass Surface (No Primer)	Herculite Glass Surface (with Primer)
Modified phenolic	1575	3200
Phenol-butyral	1650	2240
Phenol-aldehyde	0	650
Resorsinol No. 1	0	300
Modified phenolic	1170	2500
Alkyd-styrene	200	710
Resorcinol No. 2	0	390
Phenolaldehyde	300	800
Buna N-vinyl	1200	1220
Buna N-modified	1200	1215

In order to further explore the above postulation that by changing the functional group of an exposed surface an increase in adhesion would result, a number of adhesives were tested using the primed glass surface. Table III gives a comparison of the tensile strength of adhesive bonds which were determined for the two sets of conditions.

The data illustrate that increasing or improving the chemical compatibility between materials being bonded increases their attraction and ultimate bond strength. The adhesives that were definitely phenolic in composition gave the largest increases in bond strength, while the adhesive having the greater proportions of vinyl or Buna N as their base gave little or no increase over that secured from the polished surface. For example, the phenol-aldehyde which has normally no adhesion to polished plate glass increased to 650 psi. on the primed surface, while the modified phenolic doubled in bond strength. The Buna N - based adhesive gave no increase in strength from that obtained from the original polished plate glass.

Another attempt at testing the effects of surface coating was by means of an evaporated aluminum film on a glass surface which was examined for adhesion using a modified phenolic adhesive. Good adhesion was obtained between the aluminum and the adhesive. However, the aluminum film was pulled from the glass surface. The adhesion between the aluminum film and glass may be characterized as an oxide film or as a continuation of the Si-O network. However, the low tensile strength of the bond might indicate that this particular type of adhesion may be merely an adsorption phenomenon, rather than a chemical force where definite functional groups are combined.

Studies were attempted to determine any changes in polarity that may be caused by the coatings on the glass surface. De Bruyne has emphasized the polarity of the molecule in the bonding of various materials. His technique (7) was used for checking glass and modified glass surfaces using a benzene and water mixture as the standard. Other mixtures as monomeric vinyl acetate and water, styrene and water, and methylmethacrylate and water were tested for metal and glass surfaces. The results obtained from the monomer-water mixtures were identical for the respective surface as obtained from the standard. The method does not appear sensitive enough to determine the orientation of a thin surface film on glass as the results obtained were approximately the same for the primer coated surface as obtained from the polished plate glass surface.

Another attempt was made to associate the effect of functional groups of chemical compounds and adhesion. A small portion of the chemical was placed upon the glass surface, brought to the melting point, joined under sufficient pressure to produce intimate contact, and then allowed to solidify before testing in tension. Table IV gives the tensile bond strength of various functional groups.

TABLE IV.—PURE CHEMICALS AS ADHESIVES FOR JOINING GLASS.

Chemical Compound	Psi.	Description of Failure
Phenol	25	Adhesive
Diphenyl	0	No adhesion to glass
o-Hydroxybenzyl alcohol	275	Cohesive
o-Hydroxybenzaldehyde	290	Cohesive
2-4,Dichloro phenol	0	No adhesion
p-Nitrophenol	15	Cohesive
Phenyl salicylate	22	Adhesive
Salicylic acid	0	No adhesion
Glycolic acid	0	No adhesion
Cinnamic acid	0	No adhesion to glass
Stearic acid	40	Cohesive
Tartaric acid	130	Adhesion
Citric acid	320	Cohesive and adhesive
Benzoic acid	0	Adhesion
Maleic acid	110	Adhesive
Na-K-tartrate	390	Adhesive
NH_4-stearate	10	Adhesion and cohesion
Sulfur	160	Cohesive
Dextrose	230	Adhesive
Maleic anhydride	50	Cohesive and adhesive

The carboxyl group has been suggested as being effective for increasing adhesion and consequently a number of organic acids were tested. The results show that the majority of the selected acids were noneffective as adhesives for Herculite surfaces. Maleic tartaric and citric acids gave bond strengths from 110 to 320 psi. However, when Na and K were substituted for hydrogen in tartaric acid, adhesion was increased to 390 psi. One bad feature of using hot melt techniques with dibasic acids is that thermal decomposition may occur.

Various substituted phenols that were tested as adhesives, especially *o*-hydroxybenzaldehyde and *o*-hydroxybenzyl alcohol, had considerably more adhesion to glass surfaces than the pure phenol, indicating that the additional functional group may have been responsible. McBain (15) and associates have previously secured adhesion with numerous pure compounds with optical polished surfaces, and the data implied that certain end groups as C=O and —OH were effective in securing adhesion. Other investigations (9, 18, 19) have presented data to support the theory that functional groups attached to certain polymers either as end groups or side chains increased adhesion. Therefore, considerable importance may be given to functional groups of molecules as an influencing factor for obtaining adhesion. Work along this line should be continued to establish their association.

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A New Interpretation of Heat Distortion Data of Plastics

By L. S. Moody and K. B. Goldblum[1]

Synopsis

The graph of the log of deflection in mils *versus* the log of the absolute temperature with regard to heat distortion data has led to some interesting observations. A marked difference between the behavior of thermoplastic and crosslinked materials is shown. Interpretations are presented for each case. The heat distortion test is put on a somewhat sounder thermodynamic basis.

THERE has been a growing feeling that it should be possible to relate the shape of the heat distortion curve to parameters which could be related to the known physical constants of the plastic materials under test. For instance, it might be possible to relate the yield point in some way to that fraction of the polymer having the lowest molecular weight. While specific correlations were not obtained, an empirical equation was arrived at which seems to allow the interpretation of the heat distortion data for a thermoplastic material.

The heat distortion test as now conducted is arbitrary in that one point (the 10-mil point) is selected from a great number of possible points. It has been customary to consider the curve of deflection *versus* temperature as having some significance. Frequently the deflection in mils, F, was plotted against the temperature, t, in degrees centigrade. However, little insight into the nature of the physical process occurring was obtained from these plots.

Method

The heat distortion temperature of a plastic is defined in A.S.T.M. Tentative Method D 648[2] as that temperature at which a 5 by $\frac{1}{2}$ by $\frac{1}{2}$-in. bar is distorted 0.010 in. (10 mils) at its center under a maximum fiber stress of 264 psi. between 4-in. supports when heated at a rate of 2 ± 0.2 C. per min. In the General Electric Company

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[1] General Electric Company, Plastics Laboratory, Pittsfield, Mass.

[2] Tentative Method of Test for Heat Distortion Temperature of Plastics (D 648 – 45 T), 1946 Book of A.S.T.M. Standards, Part III-B, p. 872.

Plastics Laboratory it has been customary to substitute a smaller test specimen $\frac{5}{8}$ by $\frac{3}{8}$ by $\frac{1}{8}$ in. (dynstat sample) for the standard bar when only small amounts of material are available. Under these conditions, a 5-kg. weight is substituted for the standard 2.5-kg. load. The data obtained with the smaller pieces under the greater load have been found in numerous comparative experiments to agree quite well with the data obtained under the standard test conditions if six degrees are deducted from the heat distortion temperature when the smaller piece is used.

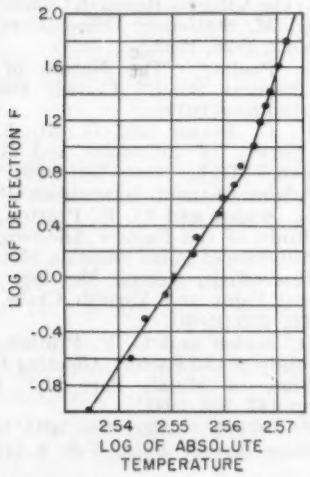

Fig. 1.—Log of Deflection in Mils *versus* Log of Absolute Temperature Plot for a Polystyrene, Dynstat Size Specimen.

Data and Discussion: Thermoplastic Materials

To repeat the long list of empirical relations which were tried in the attempt to correlate the data would only be time consuming. The simple relation that was finally arrived at was $F = KT^m$ where F is the deflection in mils, T is the absolute temperature in degrees Kelvin, and K and m are arbitrary parameters. It is obvious that a plot of log F in mils *versus* log T would give a linear graph of slope m. Applying this to thermoplastic materials such as polystyrene and cellulose acetate, graphs of which Figs. 1 and 2 are typical were obtained.

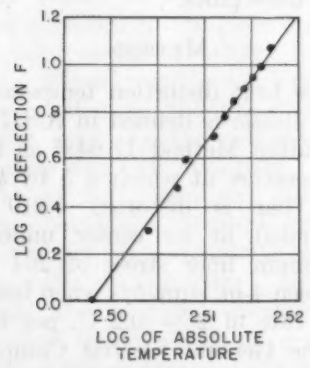

Fig. 2.—Log of Deflection in Mils *versus* Log Absolute Temperature Plot for a Cellulose Acetate, Dynstat Size Specimen.

In general, for commercial polystyrenes (Fig. 1) it was found that the graph resolved itself into two straight lines intersecting at a characteristic temperature regardless of the source of the material. This intersection was also found to be characteristic when the dynstat samples were used with the increased weight. While only incomplete data (up to the 10-mil point) were available for the cellulose acetate and no break in the line was observed, it is our conviction that when more complete plots can be made, the characteristic graph will be obtained.

For purposes of reference, the lower line of these plots was called c and the upper line b. The intersection of the two lines c and b was called t_k.

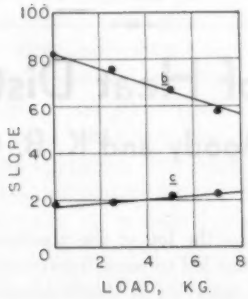

Fig. 3.—Change in Slope of c and of b with Changes in Load of Polystyrene, Dynstat Size Specimens.

An experiment was made to determine the manner in which c, b, and t_k varied with the load used. The samples in this experiment were molded from polystyrene in a dynstat sample transfer mold. This mold makes five identical samples per shot. Therefore, these pieces should be very similar as far as their thermal histories are concerned. It was found that the slope of c was nearly invariant with load while the slope of b was dependent on the load as shown in Fig. 3. The graphs of t_k and of the heat distortion temperature *versus* load as shown in Fig. 4 demonstrate that while t_k is essentially invariant with changes in load, the 10-mil heat distortion temperature decreases with increasing load. The deflection *versus* temperature data for this experiment are shown in a somewhat idealized form in Fig. 5.

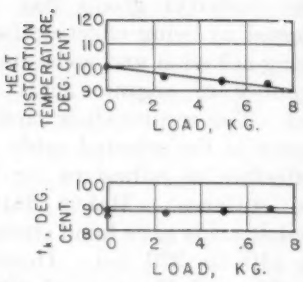

Fig. 4.—Change in Heat Distortion Temperature and in t_k with Changes in Load of Polystyrene, Dynstat Size Specimens.

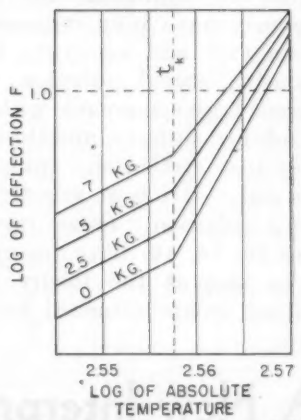

Fig. 5.—Composite Plot of Log of Deflection in Mils *versus* Log of Absolute Temperature at Various Loads. Polystyrene Dynstat Size Specimens.

The following interpretation is offered as an explanation of the above data. Region c is that region in which thermal expansion and spreading of the chains of the plastic material are the principal physical processes. This region should not be much affected by changes in load except over long periods of time. The inflection point, t_k, marks the end of the primary process and might be called the second order transition point under the conditions of the test. Above t_k the chains have sufficient thermal energy to rotate and pass one another. Therefore, in region b plastic flow is encountered and the slope of b is very load sensitive. No explanation has been found for the fact that the slope of b decreases with increasing load.

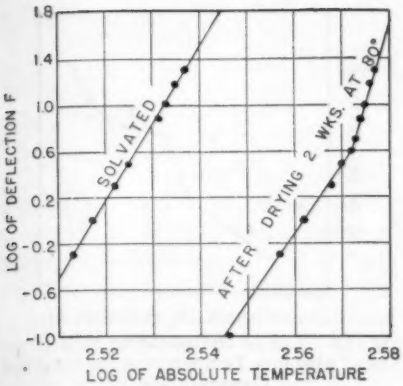

Fig. 6.—Log of Deflection in Mils *versus* Log of Absolute Temperature Plot for Polystyrene Solvated (Toluene) and After Drying Two Weeks at 80 C.

If a plasticizer or solvent is added to polystyrene to spread the chains, one would expect that the *c* region would disappear and only the *b* region would be found.[3] In Fig. 6 are shown the heat distortion data for a polystyrene sample before and after it has been freed of solvent (toluene). It is interesting to note that the typical curve is developed after the solvent has been more or less completely removed.

Attempts to relate slopes *c* or *b* to the molecular weight have not been successful. This may be due to the large experimental error in determining these slopes. However, it has been found that t_k is essentially independent of molecular weight (as indicated by specific viscosity at the same concentration) at least in the range usually found in commercial polymers. This is illustrated in Fig. 7.

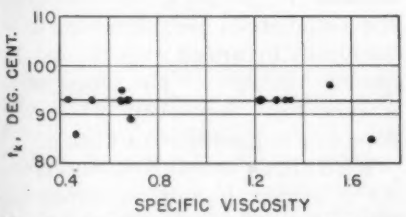

Fig. 7.—Variation in t_k with Specific Viscosity of a Series of Commercial Polystyrenes.

For a thermoplastic material then, the deflection *F* in mils is found to be a simple relation to the absolute temperature *T*. After this relation had been found, Nutting[4] published an equation which is broader in scope. Nutting's equation was obtained from a study of the flow of pitch:

$$F = At^n p^m T^r$$

where:

A, n, m, and r = constants,
F = the deformation,
t = time,
p = pressure, and
T = the absolute temperature.

Since p^m would be constant during the heat distortion test, and if it is assumed that the time factor is not too important, Nutting's equation reduces to that which has already been shown, namely, $F = KT^c$ below t_k and $F = K'T^b$ above t_k.

With regard to the constancy of the time factor t^n in Nutting's equation, it may be argued that in this paper straight lines are being drawn for slow sloping curves. However, it has been shown experimentally (and evidence has been presented at an A.S.T.M. meeting)[5] that over a reasonable range the rate of heating causes no great changes in the results. It could undoubtedly be shown that if the rate of heating were much reduced, some changes would be found.

The effect on the values of *c*, *b*, and t_k of small constant changes such as might be found if the gage were off by 0.1 mil was studied. Neither *b* nor t_k was affected. However, the slope of *c* varies considerably. Despite this possibility for error in the value of *c*, it was felt that the dial gage should be set at zero, since if the equation were obeyed, the deflection at room temperature should be exceedingly small so that the actual error in the setting would also be exceedingly small.

[3] R. F. Boyer and R. S. Spencer, *Journal of Applied Physics*, Vol. 16, p. 594 (1945).
[4] P. G. Nutting, *Journal*, Franklin Institute Vol. 242, p. 449 (1946).

[5] D. E. Strain, E. I. du Pont de Nemours and Co., Wilmington, Del., reported at the meeting of Section E, Subcommittee III of A.S.T.M. Committee D-20 on Plastics, held on March 2, 1943, that the rate of heating may be varied from ½ deg. per min. to 2 deg. per min. without significant change in the heat-distortion results.

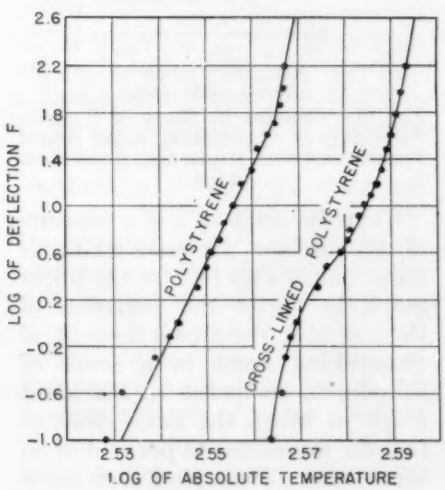

Fig. 8.—Log of Deflection in Mils *versus* Log of Absolute Temperature Plots for Standard Bar Specimens, Commercial Samples of Polystyrene and Crosslinked Polystyrene.

Data and Discussion: Crosslinked Materials

So far in the discussion, only the thermoplastic materials have been considered. The curves obtained from the log deflection *versus* log absolute temperature plot for crosslinked materials is more difficult to explain. In Fig. 8 are shown the graphs of a commercial polystyrene and a lightly crosslinked polystyrene. The latter is strikingly different from the former. In the latter the *c* region has completely disappeared. Little or no deflection occurs until the t_k temperature is reached. At this point an abrupt yielding takes place followed by a more gradual change. This is followed finally by a region of highly accelerated yielding of the test specimen.

A possible interpretation of this behavior is based upon the supposition that in a lightly crosslinked material the theory of probability suggests that there will be regions which will be more highly crosslinked than the regions between them. However, there is enough crosslinking in all regions so that the *c* line which denotes the chain spreading process is not found since the chains are too firmly bound to one another for much spreading.

When t_k is reached, flow would occur within the crosslinked region until the crosslinks have all tightened up in a particular region. Then the flow would slow somewhat. Finally, at higher temperatures, one crosslinked region would tend to flow past another and so a second type of flow would begin. It is assumed, as stated before, that some crosslinking exists in the interregion spaces so that the second type of flow should not continue indefinitely. No limit has been found even with dynstat size pieces up to several hundred mils deflection.

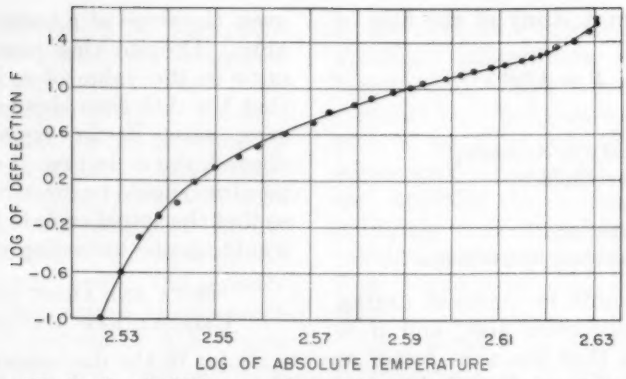

Fig. 9.—Log of Deflection in Mils *versus* Log of Absolute Temperature Plot for a Highly Crosslinked Polymer.

The shape of the curve for a highly crosslinked polymer can be predicted from the preceding discussion of the lightly crosslinked system. The major difference between the two is that in the highly crosslinked system, there would be little or no flow of one region past another. The predicted curve should, then, show an abrupt rise followed by a leveling of the curve to a more or less horizontal line. A curve for an actual specimen is shown in Fig. 9. The apparent upsweep at the end of this curve was the result of the gradual cracking and breaking of the test specimen.

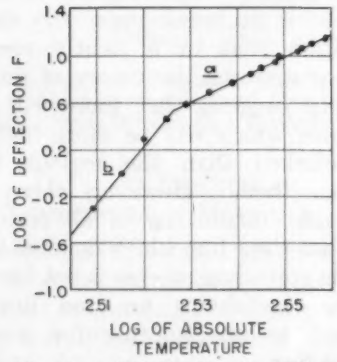

Fig. 10.—Log of Deflection in Mils *versus* Log of Absolute Temperature Plot for a Cross-linked Polymer Showing Regions *b* and *a*.

It was found in examining certain materials using the dynstat specimens that the data for these crosslinked materials could be resolved into two straight lines as shown in Fig. 10. The upper line was designated *a* and the lower, *b*. The slope of these lines is dependent on the load used. However, for constant load, it was found that the slope of *a* was a measure of the amount of crosslinking. If there were no crosslinking agent present, line *a* would be a continuation of *b*, and for very highly crosslinked materials, line *a* would be parallel to the abscissa. The slope of *a* was found to decrease in more or less regular fashion with increasing density in a series of samples of a polymer whose density was known to increase with increasing amounts of crosslinking. The slope of *b* was affected only slightly by increasing crosslinking. However, t_i, the temperature at which lines *a* and *b* intersect, was found to increase with increased crosslinking.

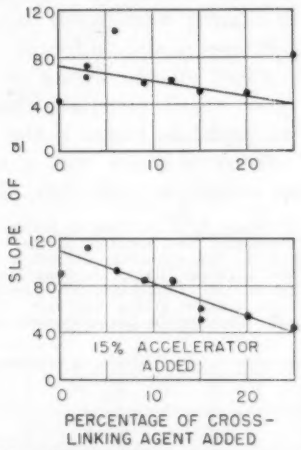

Fig. 11.—Changes in Slope of *a* *versus* Percentage of Crosslinking Agent Added Without and with 15 per cent Accelerator Added.

That the slope of *a* is a measure of the amount of crosslinking is borne out in Fig. 11. In the upper graph is shown the variation of slope *a* with the added amount of crosslinking agent in a series of samples as compared to the lower graph in which the same series of samples was added 15 per cent of an accelerator. These plots show quite clearly that the slope of *a* is a function of the degree of crosslinking and that the behavior of the change in slope *a* can be predicted.

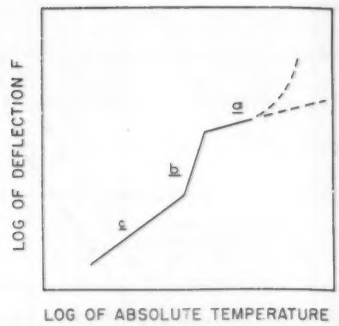

Fig. 12.—Log of Deflection in Mils *versus* Log of Absolute Temperature for Idealized General Case.

General Curve

It is the opinion of the authors that the simple ideas presented here suffice to explain the thermoplastic materials and probably the lightly crosslinked materials. However, these simple concepts are insufficient to describe completely the highly crosslinked systems. For the former systems, it is felt that there exists a general curve which describes the behavior of all these materials. To date, no one sample has been found which gives the entire general curve and there is some reason to believe that it never will. In Fig. 12 is shown the plot of the general case. It is a logical combination of the thermoplastic and crosslinked curves.

Summary

The data presented in this paper have demonstrated that for a thermoplastic the simple relation $F = KT^c$ is obeyed up to the temperature t_k. Above this point the relation $F = K'T^b$ is followed. For commercial polystyrenes, t_k is essentially invariant with changes in specific viscosity. The slope of *b* is very load dependent while the slope of *c* is insensitive to load.

With highly crosslinked materials, the *c* region is not in evidence. The curves show the *b* region in addition to an *a* region. The slope of *a* is to a great extent related to the degree of crosslinking of the polymer.

In the case of neither the thermoplastic nor the crosslinked polymers do the authors feel that the final picture has been presented. The ideas and data given here have been brought forth in the hope that they may be of some assistance to other workers in this field.

One-Millionth Second Radiography and Its Development*

By Charles M. Slack[1] and Louis F. Ehrke[1]

IN THE fall, of 1945 radiologists and roentgenographers observed the fiftieth anniversary of Roentgen's discovery of the Roentgen Ray, or, as we usually refer to it, the X-ray. It is fortunate that this anniversary coincides with the release of some of the developments which took place in X-ray technique under the stimulation of the war years, since we may thus bring up to date the survey of the progress which has been made in the X-ray art in the last century.

This paper will consider the great reduction in exposure times which has been made since Roentgen's period and particularly the latest development which permits radiographs to be made through reasonable thicknesses of metal in the extremely short time of one millionth of a second.

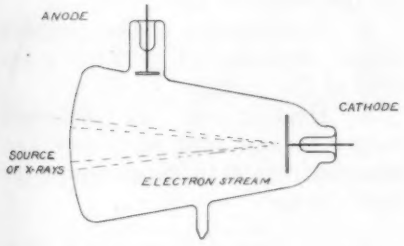

Fig. 1.—A Gas Discharge Tube of the Type Used by Roentgen When He Discovered X-Rays.

The glass wall of the bulb became the X-ray emitter under electron bombardment.

Roentgen's original tube was constructed of a lime glass bulb provided with two electrodes as illustrated in Fig. 1. When voltage from an induction coil was applied between the anode and cathode, the gas remaining in the tube was ionized and the resulting bombardment of the cathode by positive ions caused the emission of electrons which were accelerated toward the end of the tube. These electrons impinging on the glass end of the bulb excited X-radiation. A radiograph of a hand made with such a tube required an exposure of 1 hr. As an indication of the contribution to speed made by modern films and intensifying screens, a similar radiograph was made in our laboratory using a replica of Roentgen's tube excited by a 20-kv. spark coil in 5 min. on modern film with one intensifying screen.

The use of a metal target instead of the glass end of the X-ray bulb as the source of X-rays was also investigated by Roentgen and this factor added greatly to the efficiency of X-ray production. In the modern conventional X-ray tube of the hot cathode type introduced by Coolidge in 1913,[2] the source of electrons is a hot filament, and the tube is so well exhausted that no appreciable ionization of the type responsible for the functioning of Roentgen's tube takes place. A modern version of a hot cathode X-ray tube incorporating the line focus principle which permits the actual size of the focal spot to be greater than the radiographically effective size, permitting greater energy dissipation, is shown diagrammatically in Fig. 2. With this tube, a radiograph of a hand may be made in 12 milliampere-seconds at a suitable voltage using intensifying screens.

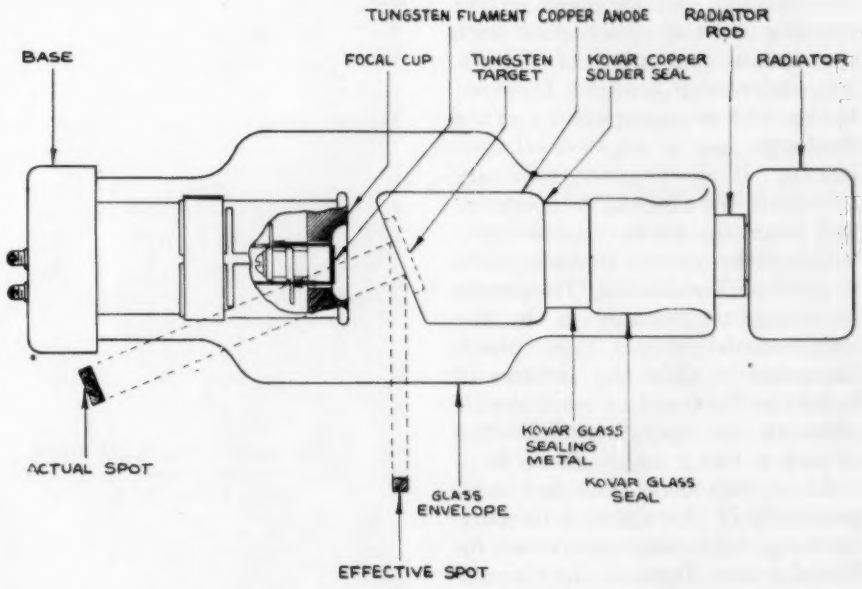

Fig. 2.—A Typical Modern Hot Cathode X-Ray Tube.

The electrons are furnished by a hot filament and bombard a tungsten target, generating X-rays.

The tube and apparatus to be described will make such a picture in 1 microsecond. Of course, since the amount of X-rays emitted in such a short time must be sufficient to produce the same photographic effect as the conventional X-ray tube produces in much longer exposure times, the current through the high-speed tube must be proportionately increased. This requires that electron currents of 1000 to 2000 amp. be available. Compared to the usual output of 10 to 1000 milliamp., this is an enormous increase and is not to be obtained by conventional means. The dissipation of this amount of energy is an important factor in the design of the tube. This will be discussed later in this paper.

Early Attempts at Ultra-Speed Radiography

The first effective step in this direction was taken by Max Steenbeck in 1938, by the discharging of

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* Presented at a Symposium on Ultra-High Voltage Radiography sponsored jointly by A.S.T.M. Committee E-7 on Radiography and the American Industrial Radium and X-ray Society, held in Cleveland, Ohio, February 8, 1946.

[1] Lamp Div., Research Labs., Westinghouse Electric Corp., Bloomfield, N. J.

[2] W. D. Coolidge, *Phys. Rev.*, Vol. 2, p. 409 (1913).

a condenser through a tube consisting of two mercury pools connected by a length of heavy capillary tubing. When the condenser discharged across this tube, a cathode hot spot formed on one of the pools and electron current flowed through the capillary and impinged on the mercury of the other pool with consequent generation of X-rays. At ordinary temperatures, however, the current is uncontrolled and the discharge has a negative characteristic. It is, therefore, necessary to control the ambient temperature and hence the pressure in the tube within rather narrow limits in order to produce X-radiation. The proper operating temperature is in the neighborhood of 0 C. Steenbeck succeeded in obtaining pictures of bullets in flight and in wood blocks, although the operating difficulties of such a device are considerable.

About this same time and independently of Steenbeck, a mercury discharge tube was constructed by Kingdon and Tanis of the General Electric Co. for the purpose of testing the reciprocity law in the killing of bacteria by X-radiation. This tube was similar to that of Steenbeck in its operating characteristics but was provided with a tungsten anode. Although the exposure times were of the order of a few microseconds, no attempt was made to focus the electron beam and apparently no radiographs were made.

Development of the Field Emission Arc Tube

It was apparent that a better source of electrons than was heretofore available would have to be found if a practical tube for microsecond radiography was to be developed. The development of such a source may be briefly traced as follows. It had long been known that instability and flash-back in vacuum tubes did not depend exclusively on the degree of vacuum within the tube, but rather on the state of contamination or surface gas accumulated on the electrodes or walls of such tubes. Tubes equipped with vacuum gages had been tested and found to flash back under much better vacuum conditions than had sufficed for satisfactory operation. It was found that such disturbances were due to the emission of large bursts of electrons

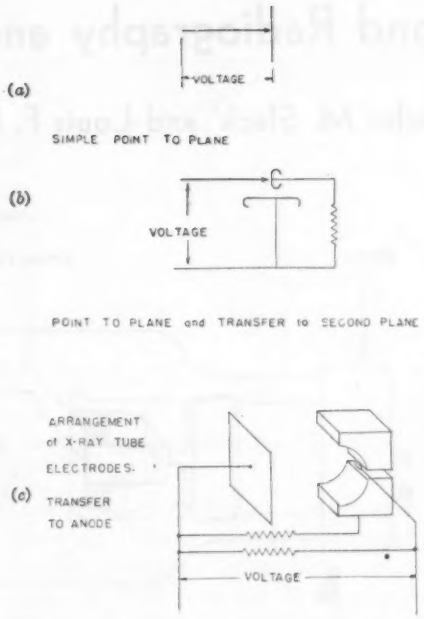


Fig. 3.—Successive Steps in the Development of the Special Cathode for the High-Speed X-Ray Tube.

(*a*) Simple point to plane.
(*b*) Stabilized arc with transfer to anode.
(*c*) Further development with focusing of the electron stream.

from contaminated surfaces or from sharp edges or points on the electrodes. Such bursts of cold emission were found to be of quite high current value and it was thought that possibly they could be turned to a useful purpose by adapting them to form a cold cathode operating under controlled conditions.

The first attempt in this direction is illustrated in Fig. 3 (*a*). A sharp point was located adjacent to a plane electrode and voltage applied between them. Under high vacuum conditions, the potential gradient could be raised sufficiently high to pull electrons out of the point, even though it was cold. The consequent flow of current caused vaporization of metallic atoms and the resultant discharge degenerates into a metallic arc capable of carrying extremely high currents. However, because of the rapidly lowered resistance of the tube, the voltage in this case collapses almost immediately to a low value and appreciable production of useful X-rays is therefore precluded. Figure 3 (*b*) shows how the introduction of a third electrode enables the arc to be initiated between this electrode and the cathode. The magnitude of the current in this arc is limited by the resistance which forces the main discharge to the anode. This arrangement allows the maintenance of high voltage while current is flowing, a necessary condition for the production of X-rays. Figure 3 (*c*) shows a rough sketch of the electrode forms finally adopted and which result in some focusing of the electron beam on the anode. With this arrangement, it was possible to secure currents of the order of 1000 amp. at voltages of 300 kv. which provided sufficient X-ray output to take a picture in 1 microsecond through 1 in. of steel.

The necessity of dissipating this enormous energy in the X-ray tube imposes certain limitations on the design of the tube. As will be seen from the following analysis, the minimum permissible size of the focal spot is controlled by these energy considerations.

The energy of the impinging electrons is dissipated in four different ways:

1. In the production of X-rays. This accounts for a fraction of 1 per cent of the energy.
2. Light and heat radiated from the focal spot account for 1 to 5 per cent of the energy, depending on the exposure time.
3. Vaporization of the tungsten target accounts for perhaps 3 per cent of the energy.
4. Heating of the tungsten target at and near the focal spot absorbs from 90 to 98 per cent of the total energy.

It is obvious from these considerations that conduction of heat from the focal spot area to the surrounding tungsten must be relied on to play the major role in heat dissipation. Since for any total quantity of input the amount of heat conducted from a given area depends on the duration and the difference in temperature, it can easily be seen that the heat-dissipating ability of a focal spot will decrease as the exposure duration decreases, so that one would expect it to be quite small for exposure times of about 1 microsecond such as we are considering here. It is fortunate that the heat dissipated varies with the square root of the exposure time according to the following formula:

$$W_m = \tfrac{1}{2} T_m (\pi K c t)^{1/2}$$

where:

Fig. 4.—Electrodes of the Ultra-Speed X-Ray Tube.

W_m = the loading in total energy permitted per unit area to raise surface to temperature T_m,
K = the thermal conductivity of the anode material,
c = the heat capacity of the anode material,
t = the time of exposure, and
T_m = the temperature.

Calculated on this basis, using a condenser of 0.02 microfarad charged to 100 kv. (and assuming a discharge time of 1 microsecond) a focal spot area of approximately 16 sq. cm. would be required to dissipate the energy of the electrons without vaporizing the tungsten target. It has been found that focal areas of from one eighth to one quarter of the calculated values are sufficient in practice and that while some vaporization does occur, several thousand exposures could be given before the tungsten deposit becomes sufficiently thick to absorb the X-rays appreciably. The failure of the formula to hold in this case is probably due to a number of causes, the most important of which are:

1. The total discharge time of the condenser may be several times that of the X-ray exposure since the intensity of the X-rays falls off rapidly with decreasing voltage.

2. A considerable portion of the electrons may be deflected from the target and give up their energy elsewhere.

3. The discharge degenerates into a low-voltage arc passing very high currents with little energy loss in the tube.

4. The time is so short that even with a high rate of evaporation the total material loss per exposure is small.

These conditions indicate that the focal spot and hence the obtainable definition can never be made as fine in a tube operating at these extremely short exposure times as they may be in tubes operating in the conventional manner. However, adequate definition for most purposes is easily obtained and rather fine definition can be obtained in one direction by taking the X-rays off the target near grazing incidence.

Figure 4 shows a photograph of the anode and cathode electrodes as used in the commercial high-speed tube. Figure 5 is a photograph of a high-speed tube taken while the discharge passed. The effect of the impinging electrons on the tungsten surface may be seen by the flash, and the paths of the incandescent tungsten particles from the focal spot are traced out by the light streaks. Some of these particles strike the tube walls and are reflected back while most seem to end at the tube wall, producing a gradual blackening on the inside of the bulb.

Circuit for Ultra-Speed Tube

The manner of operation of this device may be seen by referring to the circuit shown in Fig. 6. A bank of condensers is charged in parallel and discharged in series through the connecting spark gaps. This results in a multiplication of the charging voltage by a factor equal to the number of condensers employed. The condensers are charged through the valve tubes V_1 and V_2 by means of the transformer E_1 to a voltage somewhat lower than required to break down the spark gap. Condenser C_4 is simultaneously charged to about 1000 v. When one wishes to make the exposure, the circuit is broken at P, the charge on the grid of the thyratron T leaks off, permitting condenser C_4 to discharge through the induction coil E whose secondary gives a sufficient voltage impulse to the high voltage circuit to cause the trigger gap L to flash over. This results in the breakdown of the surge generator gaps, impressing a high voltage between G and H. Field electrons are drawn from G and this initial discharge evolves into a metallic arc between G and H which spreads out into the focusing cup and becomes a virtual cathode of apparently unlimited current-carrying capacity. Due to the action of resistance J, the discharge transfers to anode I and X-rays are produced.

Such a field emission arc cathode, capable of furnishing extremely high current densities, has found application in electronic devices other than X-ray tubes.

The time of formation of the discharge inside the tube is extremely short, and must indeed be shorter than that required to form a spark in air, since a parallel rod spark gap will jump a considerably larger spacing without the tube in

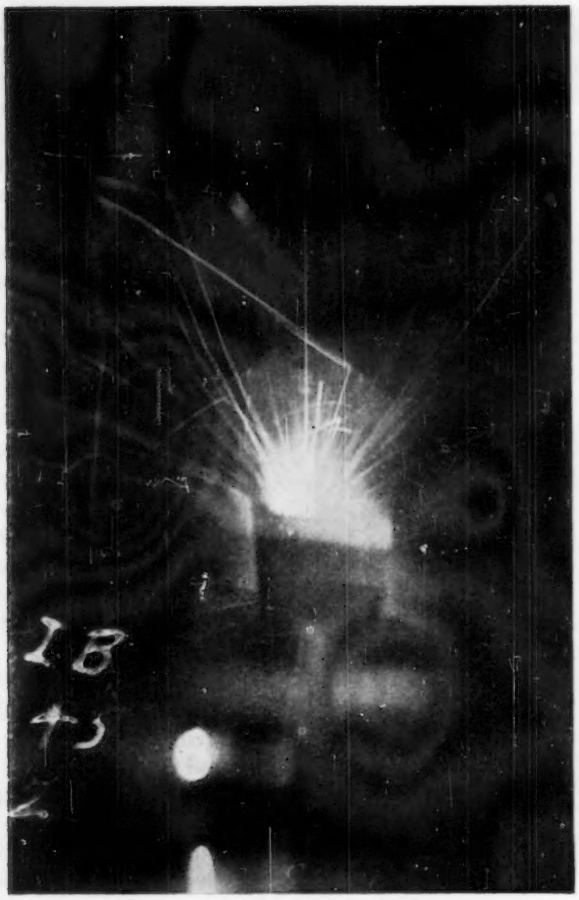


Fig. 5.—High-Speed Tube While the Discharge Is Passing Showing the Traces of Incandescent Tungsten Particles Vaporized from the Anode.

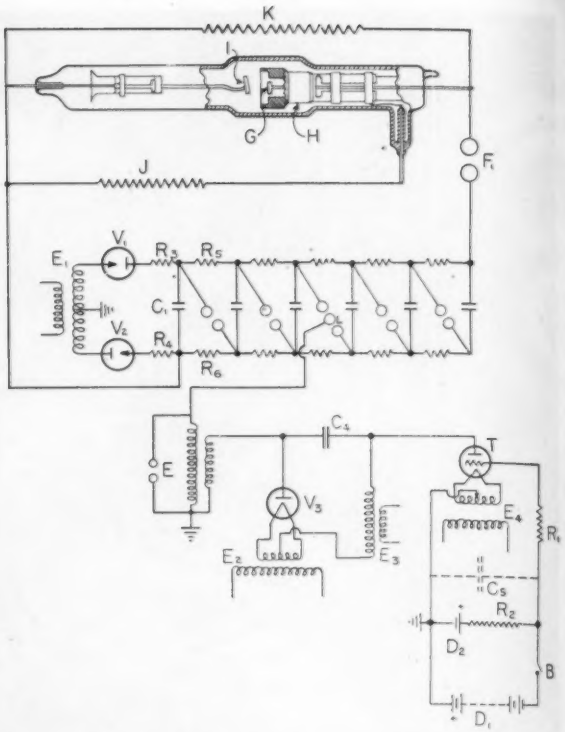


Fig. 6.—Schematic Circuit Diagram of High-Speed Tube and Surge Generator.

the circuit than with it in place. This very short breakdown time is also evidenced by the fact that the space between the external connections to the electrodes *G* and *H* is very small as can be seen from a photograph of the tube (Fig. 7) but is sufficient to prevent external breakdown, although if it were not for the rapid internal breakdown of the tubes the entire condenser voltage would be impressed between these terminals.

It may also be noted that the tube has been made shorter than would ordinarily be required for operation in air at the rated voltage of 300 kv. This is permissible because the voltage remains across the tube for too short a time for an external arc to form.

Commercial Equipment

As has been mentioned above, a circuit employing condensers has been used to energize the tube. This is the most practical way of obtaining the very high instantaneous power required to operate the tube at 1000 to 2000 amp. and 300 kv. By the use of the Marx circuit, which permits one to charge the condensers in parallel at relatively low voltage, and then discharge them in series to obtain the high operating voltage, the size and cost of the transformer and other apparatus have been kept at a minimum. As the apparatus is furnished commercially, it consists essentially of six 0.04-microfarad condensers mounted on two levels of a portable unit as illustrated in the photograph, Fig. 8. The spark gaps which connect the condensers in series at the time of discharge are adjustable for operation at various voltage settings. At the extreme lower left, the triggering transformer or impulse coil may be seen. The tube is supported in front of the portable unit and may be raised or lowered and swiveled into the most convenient position for any given application.

The exceedingly rapid breakdown time of the X-ray tube has permitted closer spacing of the condensers than would normally be the case, so that a relatively compact design has been achieved. The time constant of the trigger circuit was originally about 20 microseconds, but has been reduced to less than 1 microsecond experimentally by the use of radar com-

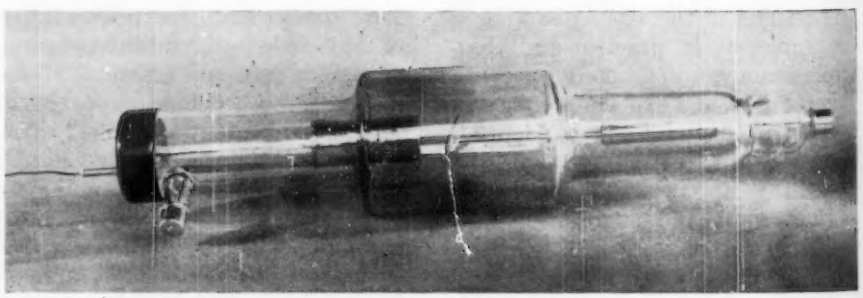


Fig. 7.—300 kv. High-Speed X-Ray Tube.
Note the small separation of the two cathode electrodes. This is possible because of the extreme rapidity with which the discharge builds up inside the tube preventing an external arc from forming.

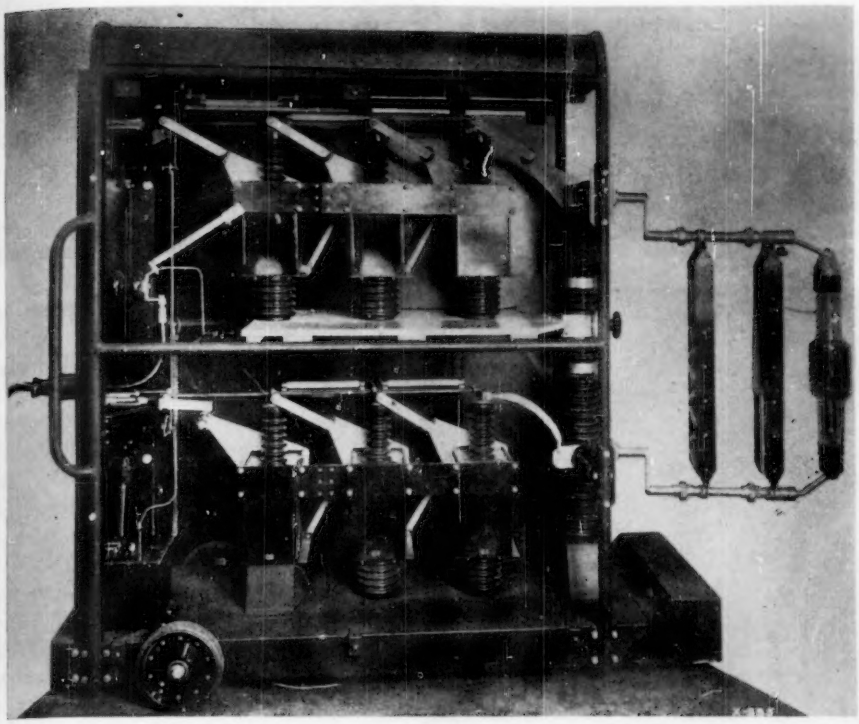


Fig. 8.—Commercial Surge Generator and Tube.

Six condensers are mounted on two levels and charged in parallel. They are discharged in series through spark gaps to produce the high voltage and high current surge needed to energize the X-ray tubes.

ponents. The time for complete discharge of the condensers through the tube is 1 microsecond or less. The time delay may be increased to any desired value by adding capacity or by increasing the value of the grid resistance of the thyratron *T*, Fig. 6. By controlling this factor, the X-ray tube may be energized at any desired time interval after the phenomenon to be radiographed has been initiated. For instance, a series of pictures showing the passage of a bullet down a gun barrel may be made by taking successive shots at different points in the cycle through varying the time constant of the timer.

The condensers are charged by a transformer delivering up to 60 kv. through a pair of rectifier tubes mounted in the transformer case. This case also contains filament transformers, a grounding relay, and two grounding resistors. The high-tension secondary winding is split, with the center tap at ground potential. The transformer is provided with four high-tension cable output sockets so that from one to four surge generators may be operated simultaneously from the same charging unit. This is often done when it is desired to produce sequence shots of some event. In such a case, the timing units are so adjusted that the generators fire in the proper order and at the desired time intervals.

Power is drawn from a standard 200 to 250-v. line through the control stand. The charging voltage may be regulated in ½-kv. steps from 30 to 60 kv. In spite of the high power used when the X-ray tube fires, due to the use of the surge generator principle, the power drawn from the lines at any time is quite small, and extra heavy wiring is not required.

Figure 9 shows an installation of two surge generators with the control panel and transformer unit

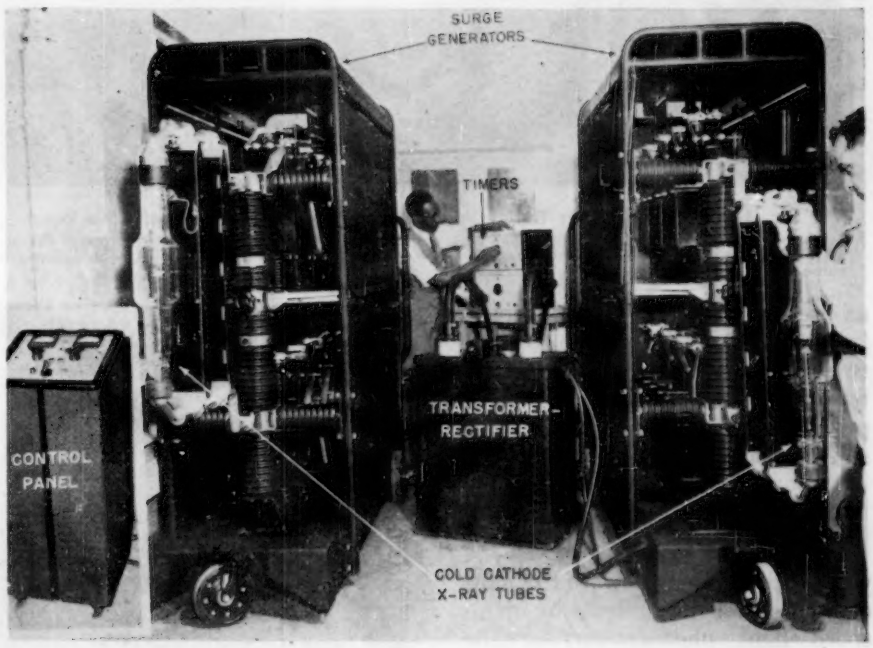


Fig. 9.—A Typical Installation of Two Surge Generators and Control Equipment.

Photograph by Picatinny Arsenal

Fig. 10.—High-Speed Radiograph of a 0.22-Caliber Bullet Passing Through a Series of Lamp Bulbs.

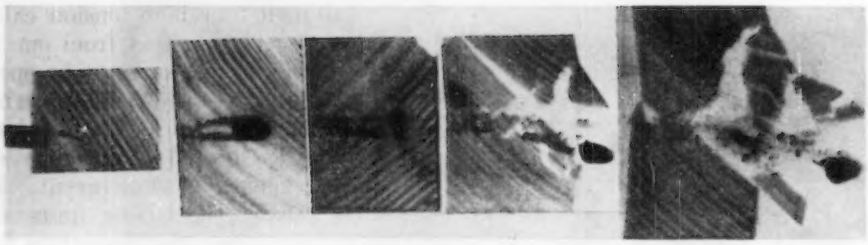


Fig. 11.—High-Speed X-Ray Pictures of a 0.22-Caliber Bullet Passing Through Wood Blocks.
Note how quickly the fibers of the wood tend to close up the hole.

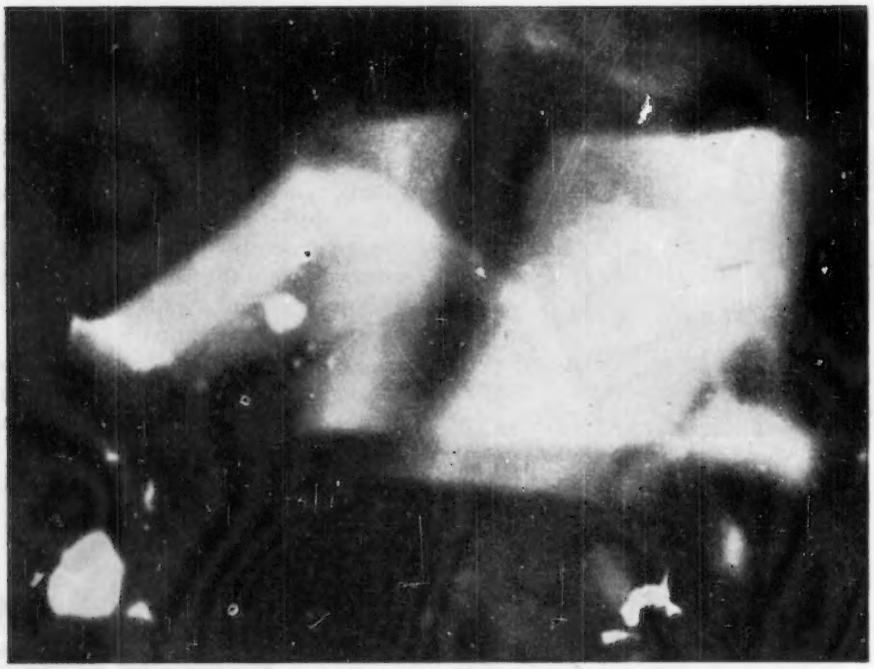


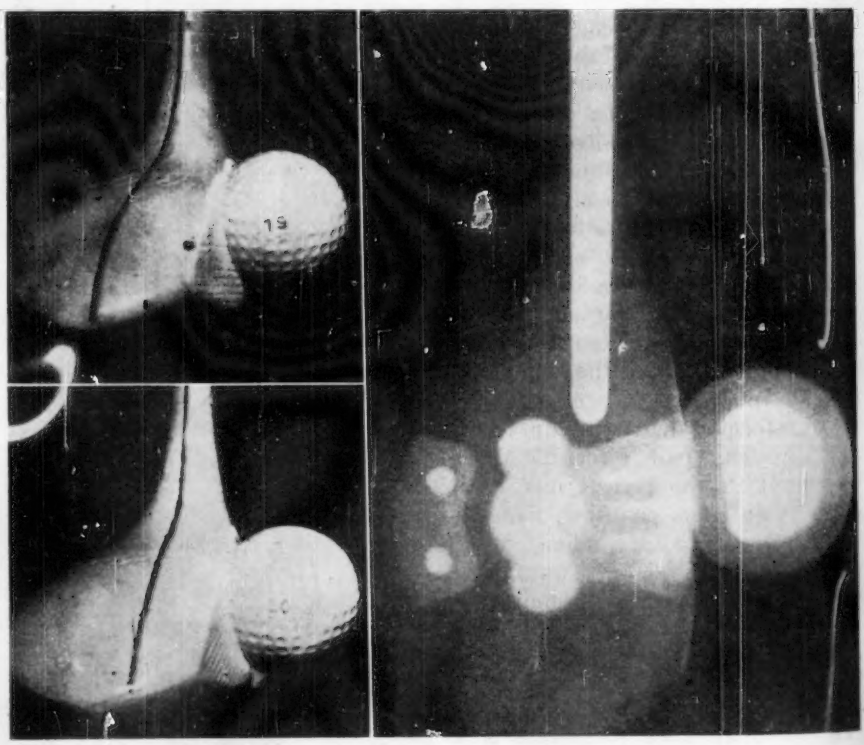
Fig. 12.—A 0.22-Caliber Bullet Passing Through a Piece of Beef Shin Bone.
This shows the destructive action of the bullet and the pressure produced in the marrow of the bone. This is a forerunner of the extensive research done on wound mechanism with the high-speed X-ray machine.

as used at Picatinny Arsenal. The tubes may be brought quite close to each other when it is necessary to get successive shots of bullets passing down a gun barrel or some similar condition.

Applications

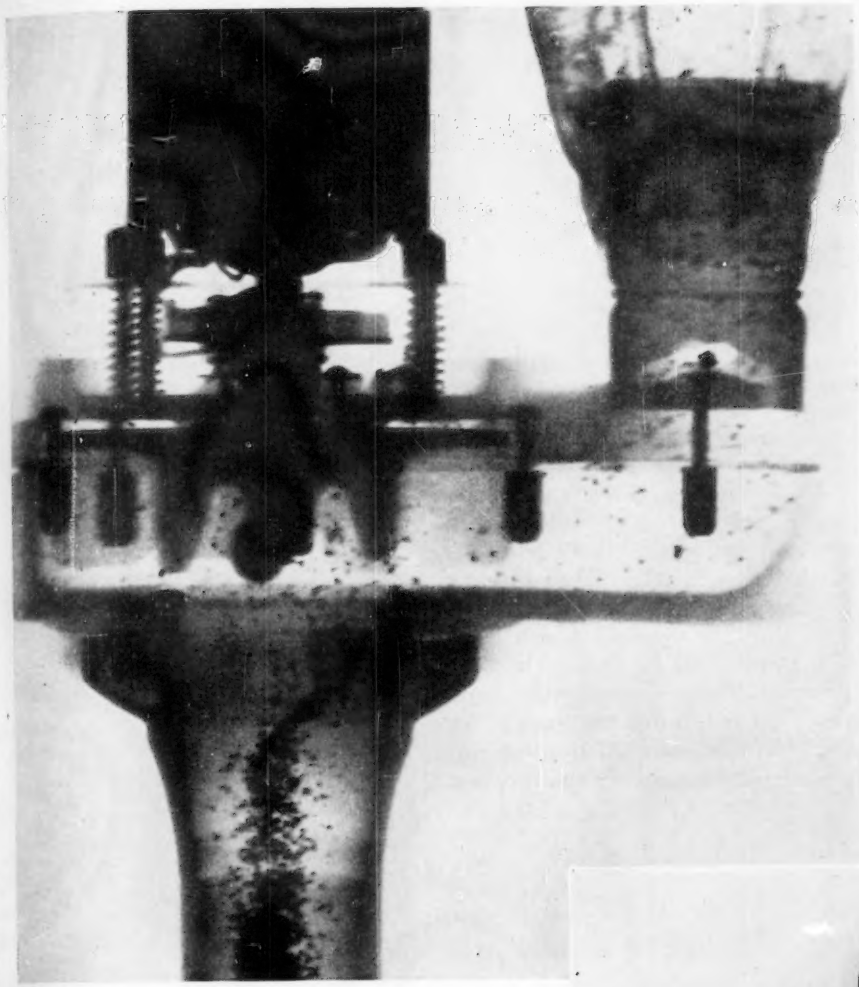
Some of the examples of the use of this apparatus which are to follow could also have been made by ultra-speed light photography by the Edgerton flash technique or by spark photography. However, even when the internal structure of the object is not essential, in the examples shown, a light picture would be so obscured by the smoke and bright flash of explosives that very little information would be obtained. Even such a simple example as the bullet passing through a series of incandescent light bulbs (Fig. 10) loses some detail due to multiple reflections when a light source is used. It is of interest to note that although the stems of the first two lamps have been carried away by the bullet, the lamp bulbs have not yet disintegrated

Figure 11 shows a series of pictures of 0.22-caliber bullets passing through similar wood blocks. This series was selected from a number of separate shots and covers the cycle from the time the bullet is just entering the block to the exit of the bullet and the splintering of the block. This is one of the first ballistic pictures made in our laboratory and was the means of stimulating interest in the ballistic possibilities of this apparatus on the part of Frankford Arsenal which resulted in the development of the commercial unit described here. The unit has found wide usage in a variety of ballistic problems at various arsenals. In many of the war project applications, there is still a great deal which has not been released. The most important probably are its application to the cavity charge effect, which is the principle of the bazooka and other rocket devices, to the study of the



(a) High-speed light picture showing clearly the compression of the ball. (b) High-speed X-ray picture showing also the compression of the core of the ball.

Fig. 13.—Golf Club Striking a Ball.



mechanism of explosives whereby it is possible for the first time to see wave motions, and finally its application to the now famous Manhattan Project. The Manhattan Project has permitted the following statement to be made: "This equipment was extensively used in connection with the development of the atomic bomb, the exact nature of which cannot be released at this time."

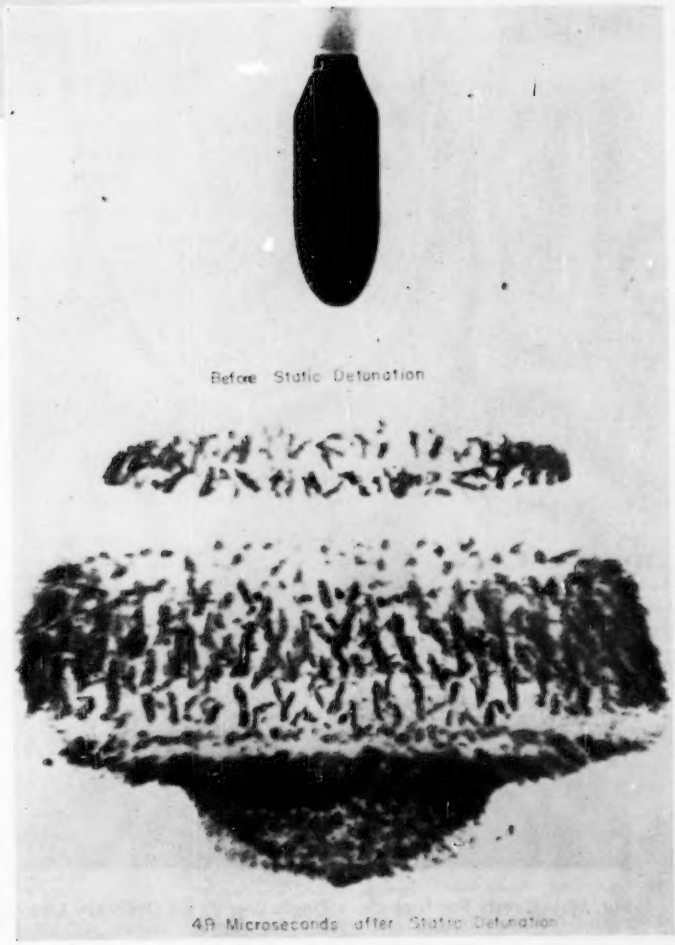
Figure 12 shows a 0.22-caliber bullet passing through a piece of shin bone. This again is a primitive example of the application of the high-speed X-ray to wound ballistics, a study carried on by a beautiful series of experiments under the direction of Dr. E. Newton Harvey under a contract between the OSRD and Princeton University.

As an indication of the application of this apparatus to sports radiography, the next two figures may be of interest. Figure 13 (*a*), shows a photograph taken by the Edgerton flash technique using visible light of a golf club striking a ball. Figure 13 (*b*) shows a corresponding radiograph made with the high-speed X-ray tube. Here the distortion of the core of the ball becomes visible as well as the distortion of the outer covering as shown in the light picture.

While the industrial applications of the apparatus have not been widely explored due to the concentration of interest on ballistic problems and other Government research programs, including that sponsored by the Manhattan District, during the war years, Fig. 14 represents a simple application in the industrial field. This is a radiograph of a vacuum cleaner in operation and shows the flow lines in the cleaner and indicates the air veloci-

Fig. 14.—High-Speed Radiograph of a Vacuum Cleaner in Operation, Showing the Lines of Flow and Velocities of the Particles in Their Passage Through the Cleaner.

Fig. 15.—Radiograph Showing the Distribution Pattern of a Model Bomb.
Radiograph by Aberdeen Proving Ground



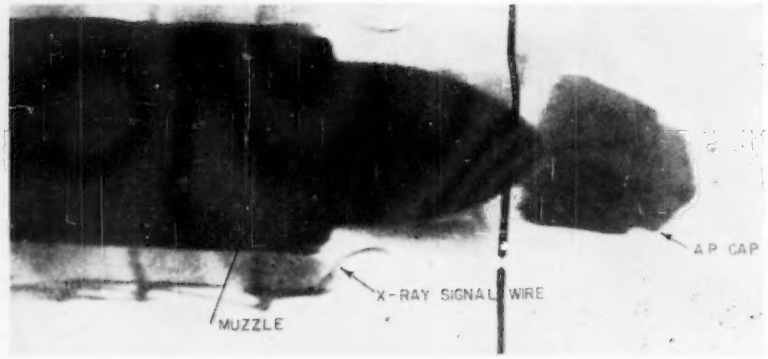


Fig. 16.—Radiograph Showing the Cause of Failure of a Bad Lot of 37-mm. Armor-Piercing Ammunition.

The armor-piercing cap has become detached from the shell and is broken up before striking the target.

Radiograph by Aberdeen Proving Ground

ties at various points. It is expected that such problems as valve motion studies, piston motion, and similar problems will prove susceptible to investigation by this means.

A great variety of work on small caliber ammunition, including incendiaries and other complex structures, has been done by this method and much valuable information obtained.

An interesting investigation into the patterns produced by various types of shells and bombs has been carried on at Aberdeen Proving Center. Figure 15 shows the static detonation of a model bomb.

Figure 16, also from Aberdeen Proving Center, shows a radiograph taken to determine the reason for the failure of some 37-mm. armor-piercing ammunition to function properly. The radiograph shows that the failure to penetrate the armor was due to the fact that the armor-piercing cap left the shell shortly after leaving the muzzle. Later on, the projectile caught up with the cap and shattered it before reaching the target.

Fig. 17.—Cavity Produced in a Dog's Leg by an Ordinary Low-Velocity 0.22-Caliber Bullet.

Photograph by Princeton Univ.

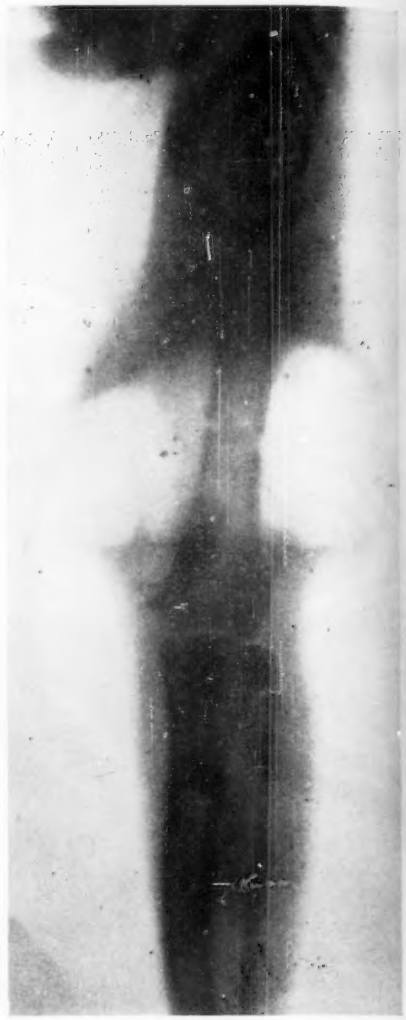


Fig. 18.—Large Cavity and Extensive Tissue Destruction Produced by a High-Velocity Projectile.

Note that the bone has been fractured although not struck by the projectile.

The ultra-speed X-ray tube has been found to be of great value in investigations dealing with the mechanism of explosives. The propagation of the explosive wave through the charge has been impossible to follow by high-speed photography or other previously available methods. The use of the high-speed X-ray, with its property of "seeing through" a light blast or cloud of smoke resulting from the burning of an explosive charge, has enabled observers to follow the progress of an explosion from ignition to com-

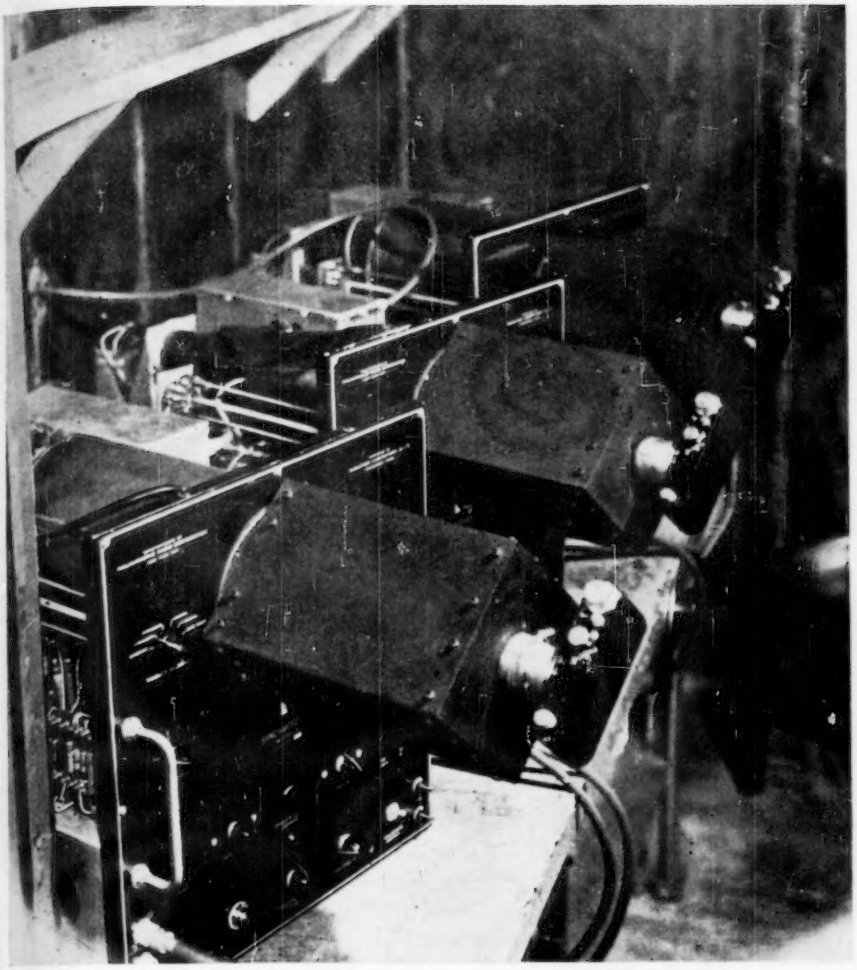


Fig. 19.—A Close-Up View of the Three Oscilloscopes and Their Recording Cameras.
One scope records the voltage wave, the second the current wave, and the third scope records the variation in the X-ray output during the exposure of less than 1 microsecond.

pletion with considerable detail and accuracy.

The high-speed X-ray has been of considerable value in the investigation of the wounding mechanism of extremely high velocity particles. Early in the war, it had been noticed that high velocity particles from fragmentation bombs and other projectiles could result in extensive deep tissue destruction although only a very small surface wound was detectable. Some work had been done in England using gelatin and water phantoms with high-speed light photography. Dr. E. Newton Harvey and his group, working at Princeton University under an OSRD contract, investigated these phenomena with the high-speed X-ray apparatus. Two of the remarkable radiographs obtained are reproduced here by special permission.

Figure 17 shows the cavity produced in a dog's leg by a 0.22-caliber low-velocity lead bullet. Contrasted to this is Fig. 18, which shows the much larger cavity with extensive tissue destruction and fracture of the bone (which was not struck), produced by a high velocity projectile.

Analyzing Equipment

In the development of this tube and generator, a fuller understanding of the functioning of the tube than could be obtained by visual or photographic means was desired. Therefore, an investigation of the current through the tube, the voltage impressed on the tube, and the resultant X-rays was undertaken. Three oscilloscopes, with the necessary amplifiers, and ionization chamber were set up in a specially constructed double shielded room adjacent to a second shielded room containing an experimental surge generator and high-speed X-ray tube. The oscilloscopes were so arranged that simultaneous records of the current, voltage, and X-ray output could be photographed. Due to the tremendous fields set up when the surge generator discharged, it was necessary to install the shielding referred to above and to use coaxial connections to the

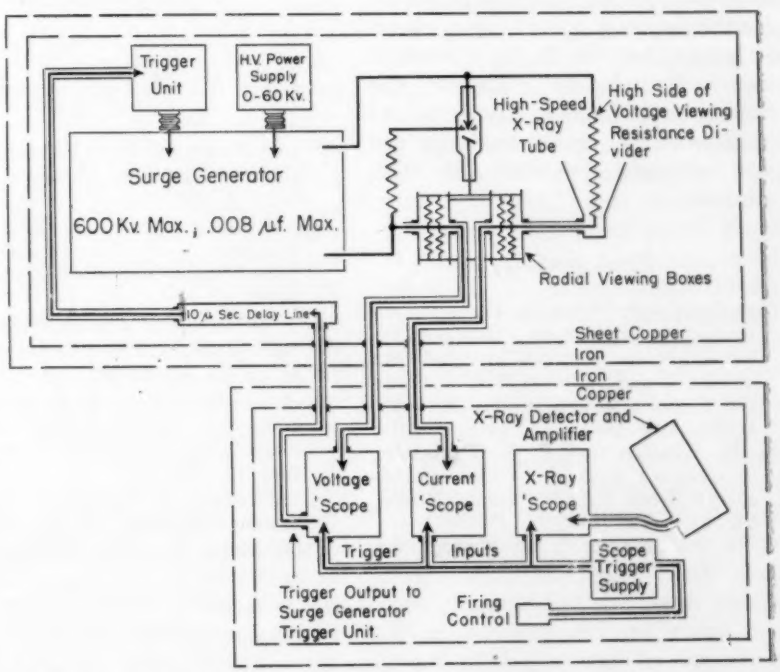


Fig. 20.—A Block Circuit Diagram of the Experimental Surge Generator Unit and Associated Oscillographic Equipment.

oscilloscopes and voltage dividing units. Figure 19 is a closeup view of the oscilloscopes showing the recording cameras. Figure 20 is a block diagram showing the circuit arrangement.

Typical simultaneous oscillograms obtained on this setup are shown in Fig. 21. It is of interest to note the extremely sharp rise in the voltage curve and the fidelity with which the X-ray output curve follows the voltage curve, falling off very rapidly as the voltage falls, although considerable current may still be passing at low voltage. Studies such as these permit more thorough understanding of the functioning of the tube and indicate the steps necessary for improvement.

Conclusions

From the foregoing examples, one may conclude that the high-speed X-ray apparatus is applicable to the investigation of a wide variety of problems in the medical, ballistic, and industrial fields. One of the most recent proposals is the investigation of the effect of the tremendous forces to which the body is subjected while being ejected from airplanes. The effect of the high accelerations necessary to accomplish this in the faster types of aircraft in use now and projected for the future is quite serious and it is hoped that the X-ray investigation will help to overcome the difficulties. Sudden decelerations produced by crash landings are also subjects for study by this method.

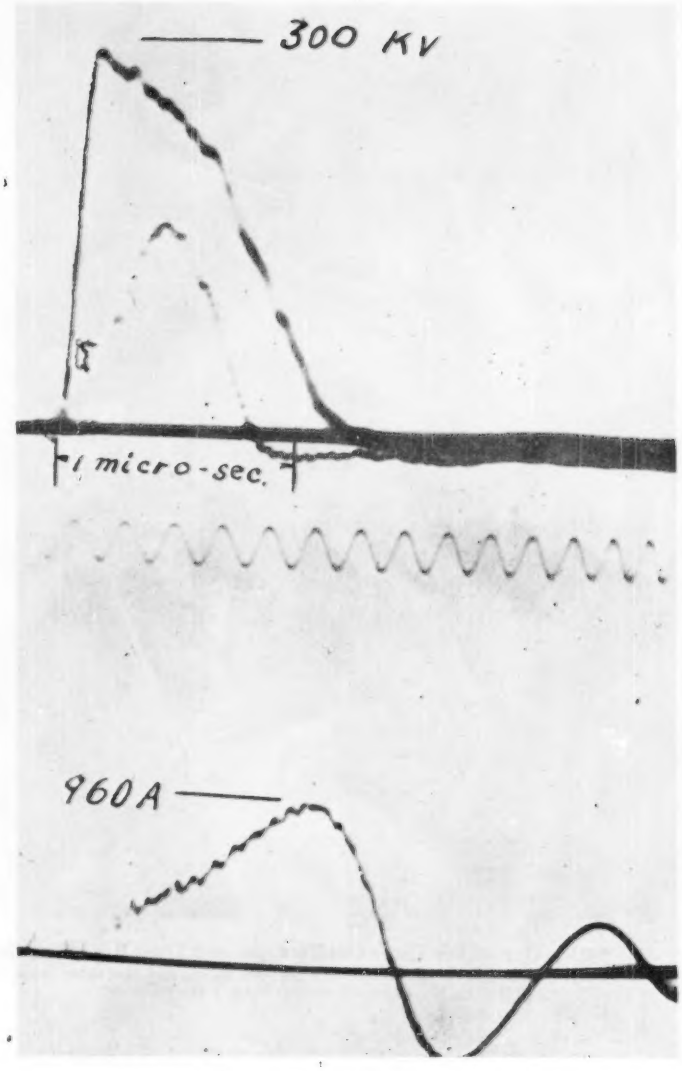


Fig. 21.—A Typical Set of Oscillograms.
The top curve shows the variation of voltage during the exposure time. The second curve shows the variation in X-ray output which follows the voltage closely, and the lower curve shows the shape of the current wave.

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Frankford Arsenal Experience with High-Speed Radiography*

By E. R. Thilo[1]

In January of 1942, there was delivered to the Laboratory Division of Frankford Arsenal the first unit of the present form of the high-speed X-ray equipment. The specification set up by Frankford Arsenal for the penetration of an inch of steel with exposures in the order of a millionth of a second had been met by the newly developed equipment so that these two factors were known. Also limited experience had been obtained with Dr. Slack's experimental equipment in the technique to be employed with this new "tool." With this rather meager backlog one could, at best, only conjecture as to the ultimate uses to which this equipment would be applied.

The first problem investigated at Frankford Arsenal was the study of what happens to a bullet when it strikes a piece of armor. Ordinary photographic methods, including high-speed photography, run into the difficulty of having the actual penetration obscured by luminous fragments thrown back at the time of impact. This difficulty is, of course, not present in the case of X-rays. This study was carried out with caliber 0.30 jacketed armor-piercing bullets. The high-speed X-ray pictures showed the flow of the jacket material and the breaking up of the core as the bullets penetrated the armor. Subsequent work has indicated that this type of work could safely be carried out with 20-mm. shell or possibly even larger shell. With the larger shell a great deal of information could be obtained concerning the behavior of the windshield and the piercing cap and the failure of the body either by bending or shatter.

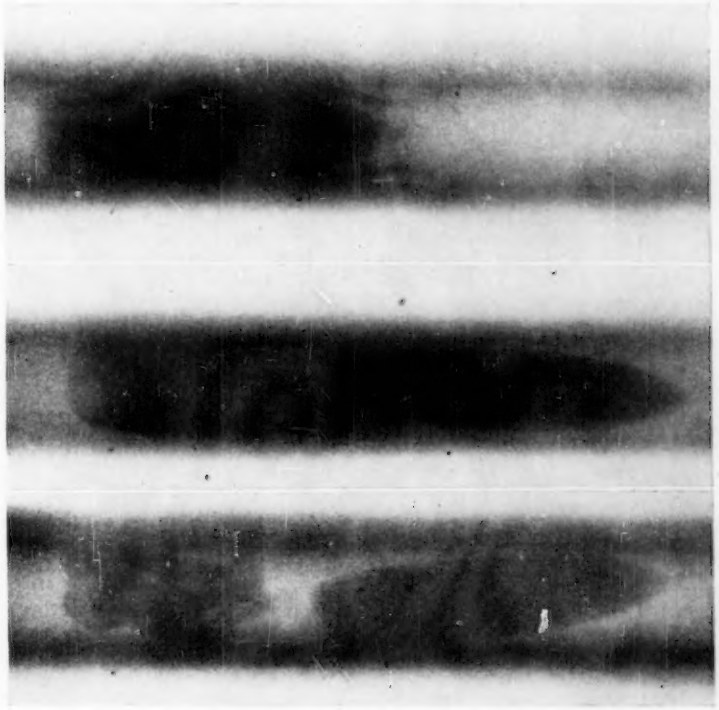

Fig. 1.—High-Speed X-Ray Pictures Taken Through a Caliber 0.50 Barrel Showing the Failure of the Bullet Inside the Bore of the Gun.

(*a*) Nose of jacket has broken open.
(*b*) Core is being blown through the jacket.
(*c*) Core has been blown ahead of the jacket. The jacket has collapsed.

The equipment is pre-eminently fitted to study the motion of internal mechanisms. In ballistics, for example, no other means is available for taking a picture of a bullet as it passes down the bore of a gun. Figure 1 shows high speed X-ray pictures taken through a caliber 0.50 barrel. The bullet jacket has failed and the steel core has been forced ahead of the jacket. Studies of this nature have not only shown the manner of failure but also indicated the cause of the failure as well. The effects of changes in the manufacture and assembly of the bullets were then followed by means of similar pictures. The motion of the piston in the gas cylinder on a Garand rifle is shown on Fig. 2. These high-speed X-ray pictures show the displacement of the piston in the cylinder at given times after the muzzle exit of the bullet. They also reveal the manner in which the operating rod spring is compressed.

Studies have also been made of the realignment of component parts inside the projectile when it is fired. A stationary radiograph is first taken. The projectile is then fired and a high-speed X-ray picture is taken of the projectile in flight. The two radiographs are then compared to determine whether any realignment has taken place. Figure 3 illustrates this procedure as applied to an experimental 15-mm. incendiary bullet. The incendiary powder has "set back" as a result of the firing and also it has assumed a concave bounding surface due to the spin of the bullet.

When an incendiary bullet functions, a bright flame completely surrounds the bullet and prevents it from being photographed. However, with the high-speed X-ray equipment it has now been possible to take X-ray pictures which show what is happening to the bullet inside the enveloping flame. In this manner it was possible to study

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* Presented at a Symposium on Ultra High Voltage Radiography sponsored jointly by A.S.T.M. Committee E-7 on Radiography and the American Industrial Radium and X-ray Society, held in Cleveland, Ohio, February 8, 1946.

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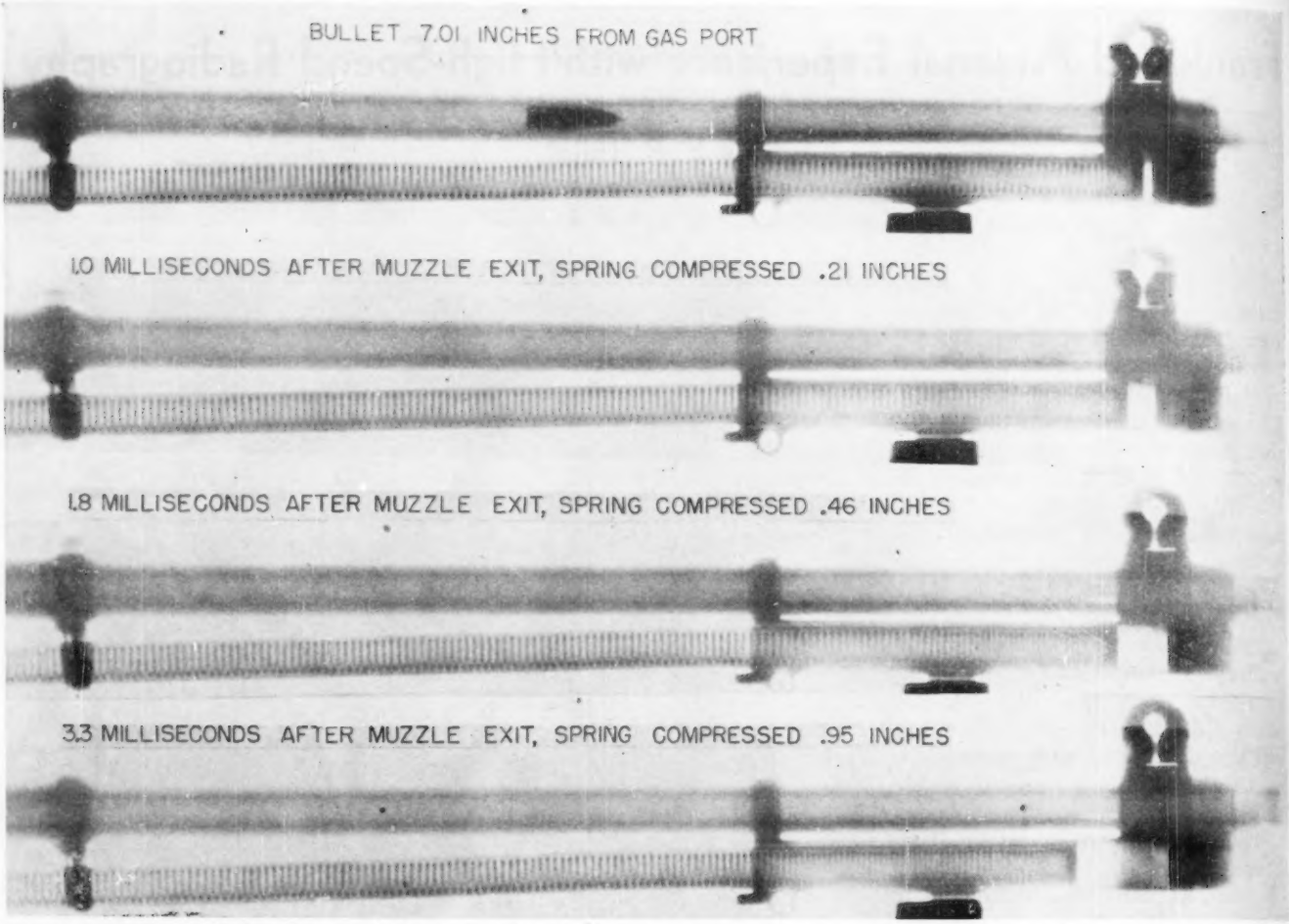

BULLET 7.01 INCHES FROM GAS PORT
1.0 MILLISECONDS AFTER MUZZLE EXIT, SPRING COMPRESSED .21 INCHES
1.8 MILLISECONDS AFTER MUZZLE EXIT, SPRING COMPRESSED .46 INCHES
3.3 MILLISECONDS AFTER MUZZLE EXIT, SPRING COMPRESSED .95 INCHES

Fig. 2.—High-Speed X-Ray Pictures of the Garand Rifle Showing Motion of the Piston and Compression of the Operating Rod Spring.

the stripping of the jacket when the incendiary bullet was fired through the duralumin skin of a plane. Occasionally, the incendiary bullet will fail and function at the muzzle of the gun. A photograph of the bright flash of the muzzle burst, as it is termed, is shown in Fig. 4. The appearance of the incendiary bullet inside the bright flame is shown on the corresponding high-speed X-ray picture (Fig. 4). These high-speed X-ray pictures revealed the details of the bullet failure and assisted in correcting the trouble.

The explosion of 20-mm. high explosive shell has been studied by means of high-speed X-ray pictures. The shells were fired through steel plates and high-speed X-ray pictures were taken at the instant of impact and at subsequent stages of the explosion process. The force of the explosion was so violent that it was necessary to place a steel plate ¼ in. thick over the cassette in order to protect it. A new protection plate was required after each shot. A series of representative pictures showing the manner in which the 20-mm. shell explodes are shown in Fig. 5. Each picture is of a different shell taken at a different stage of the explosion process.

The high-speed X-ray studies have been mainly carried out in a room of the following dimensions, 40 ft. long, 20 ft. wide, and 12 ft. high. Since the bullets and explosive shell were fired in the same room where the X-ray equipment was located, it was necessary to provide adequate protection from flying fragments for the equipment. The setup used to obtain the high-speed X-ray pictures of the functioning of the 20-mm. high explosive incendiary shell is shown in Fig. 6. The horizontal tube is suspended from the ceiling and is connected to the surge generator by means of copper tubing. No trouble has been encountered in piping the high voltage around and wide flexibility in the positioning of the tube is obtained.

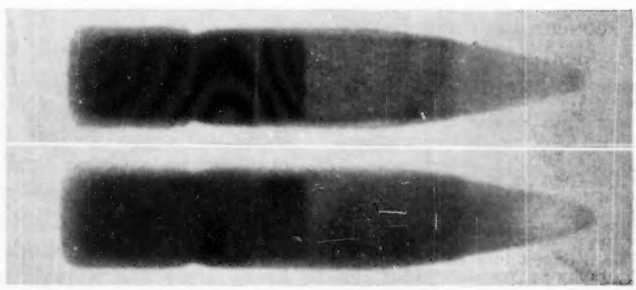


Fig. 3.—High-Speed X-Ray Study of the Realignment of Component Parts Inside a 15-mm. Incendiary Bullet When It Is Fired.
Top—Conventional X-ray of stationary bullet.
Bottom—High-speed X-ray of bullet in flight.

The vertical tube is connected directly to the second surge generator and was used to take a mutually perpendicular X-ray picture. The two X-ray pictures were taken either simultaneously or in sequence. The fragment protection enclosure is lined with $\frac{1}{4}$-in. steel plates and faced with removable plywood. Windows cut in the steel plates for the X-rays were covered with several pieces of $\frac{1}{8}$-in. thick dural. The shell fragments after passing through the steel target were stopped by a piece of armor plate placed 2 ft. beyond the target. After aligning the target plate, film cassette, and X-ray tubes, the 20-mm. cannon was loaded and the personnel left the room. The surge generators were charged from controls located outside the firing range. When the generators were fully charged, the projectile was fired. An electrical circuit was broken when the shell hit the target plate and this triggered a timing unit which was adjusted to fire the surge generators at given intervals after impact.

The equipment itself has been comparatively trouble free. The surge generator requires an occasional dusting and once in a great while the sphere gaps must be readjusted. The transformer rectifier unit has required no attention and the control unit has only required the replacement of a set of breaker points on a relay. The tubes have held up remarkably well considering the fact that they are in the same room where the gun is fired. To date 4500 exposures have been taken. The surge generators, despite their large size (7 ft. long by 30 in. wide by $6\frac{1}{2}$ ft. high), can be maneuvered with little difficulty by two people. The equipment is fairly portable. In connection with the development of a 75-mm. recoil-less rifle carried out by this Arsenal, a problem arose which necessitated the use of high-speed X-rays. The surge generator, charging unit, and control unit were moved out of doors and set up for an extended period of time and functioned satisfactorily.

As to what uses the technique of high-speed radiography will have in the postwar period, it is difficult to say. The method should be useful in studying the motion of

(*a*) The nose of the shell has passed through the plate. There has been no shift of the detonating parts of the fuze. Approximately 20 millionths of a second after impact.

(*b*) The shell has started to swell in the region of the bourrelet. The booster has not yet detonated.

(*c*) The shell has swelled more than the shell pictured above. The maximum swelling is still in the region of the bourrelet. The booster has detonated. The ring of petals about the shell can be seen. Approximately 35 millionths of a second after impact.

(*d*) The shell body has swelled to almost twice normal diameter. The petals have constrained the bourrelet region of the shell from swelling as rapidly as the body of the shell. The base of the shell has swelled very little.

(*e*) The shell has ruptured. The base of the shell is starting to mushroom out. The constraining influence of the petals is evident. Approximately 60 millionths of a second after impact.

(*f*) The base of the shell has mushroomed out even further. The nose and some of the shell fragments have passed out of the constraining influence of the petals.

(*g*) The fragments of the base of the shell are passing through the hole. The petals have curled back to produce a hole approximately $2\frac{1}{2}$ in. in diameter. Approximately 100 millionths of a second after impact.

(*h*) The shell fragments are almost all completely through the plate. The petals have continued to curl back to produce a hole approximately 5 in. in diameter.

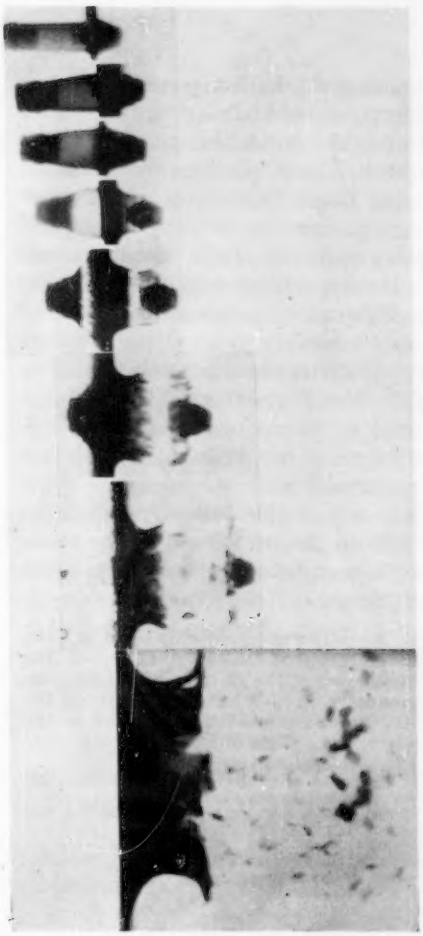


Fig. 5.—High-Speed X-Ray Pictures of the Functioning of 20-mm. High Explosive Incendiary Shell When Fired Through a $\frac{1}{8}$-in. Steel Plate Placed Normal to the Line of Fire.

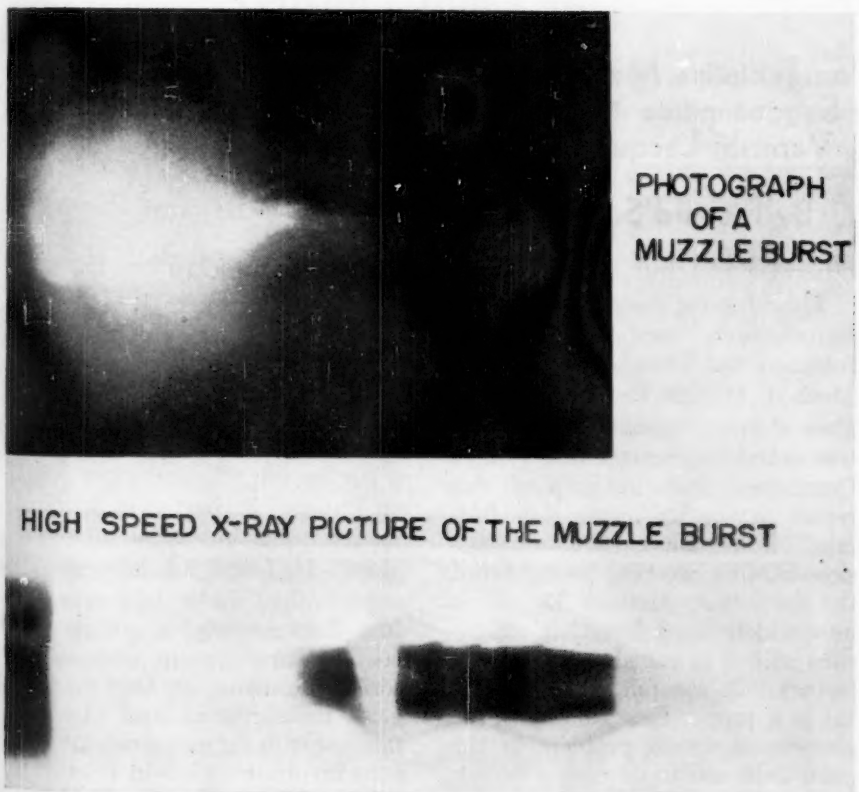


Fig. 4.—High-Speed X-Ray Study of an Occasional Failure Experienced with Incendiary Bullets.

The bullet functioned prematurely and burst at the muzzle of the gun.

internal mechanisms, such as valve components, enclosed springs, etc. It might be possible to take high-speed X-ray pictures of castings being poured. Pictures which show the manner in which the metal flows into the form should assist in the development of better casting techniques. The preceding illustrations cover in general the various applications that have been made with the high-speed X-ray equipment at Frankford Arsenal. They show what has been done with the equipment and it is hoped that they will enable industry better to evaluate the usefulness of the technique as applied to their particular problems.

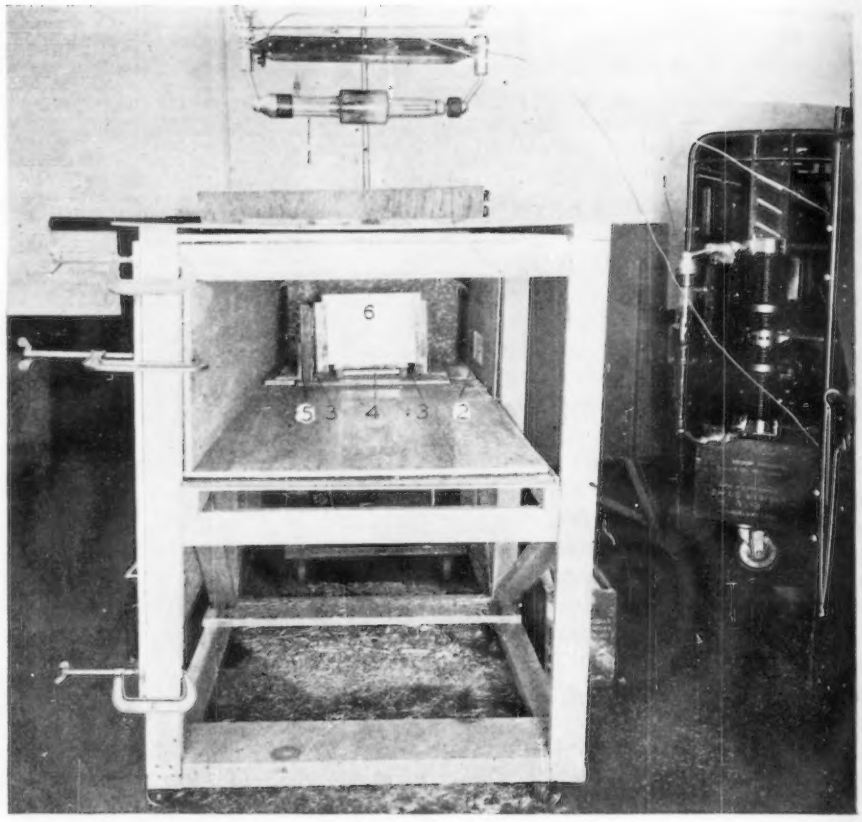


Fig. 6.—Experimental Setup Used to Take the High-Speed X-Ray Pictures of the Functioning of the 20-mm. High Explosive Incendiary Shell When Fired Through the ¼ in. Steel Plate Placed Normal to the Line of Fire.

1—X-ray tubes.
2—Window in ¼-in. steel plate, other side fragment protection removed.
3—Steel protection plate placed over the film cassette.
4—Film cassette.
5—Holder for vertical X-ray cassette.
6—Steel target plate.

The Gloss Measurement of Paint Finishes

Report and Recommendation on Tentative Method of Test for Specular Gloss of Paint Finishes (D 523-44 T)[1] by Subcommittee X on Optical Properties, of Committee D-1 on Paint, Varnish, Lacquer, and Related Products

By Richard S. Hunter[2]

DURING the past ten years, gloss measurement has become an established test procedure in the paint industry. This test procedure was first introduced through the efforts of A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer and Related Products. Measurements of gloss are now used to classify paints as either flat, eggshell, high gloss, or in one of the two intermediate ranges between these three common gloss classes. Gloss measurements are also used to evaluate small differences in shininess between surfaces that are otherwise identical in appearance.

The following report describes the introduction, use, and possible future development of A.S.T.M. Method D 523 for the specular gloss of paint finishes. The author was asked by Subcommittee X of Committee D-1 to prepare this report during its meeting in Buffalo, N. Y., June, 1946. Discussion at this meeting brought out the fact that Method D 523 is now widely used but that experience with it is not altogether satisfactory. It was felt that the present is a proper time to survey the gloss-measurement problem in the paint field and to develop a better, more reliable method of gloss measurement. The present report is the start of such a survey.

Events Leading to the Development of Modern D 523

Members of Committee D-1 have been actively interested in the gloss problem since at least 1933. In that year M. Rea Paul conducted a survey for Subcommittee XVIII on Physical Properties of Materials to determine industrial interest in gloss. He found this interest to be considerable. In the following years Mr. Paul repeatedly arranged for cooperation between paint laboratories cognizant of the need for gloss measurement and physicists familiar with the measurement problems involved. Thus in 1936 A. H. Pfund of Johns Hopkins University cooperated with Mr. Paul and his group.

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

[1] 1946 Book of A.S.T.M. Standards, Part II, p. 1587.

[2] Henry A. Gardner Laboratory, Inc., Bethesda, Md.

Mr. Pfund at that time had a glossmeter[3] specially suited to the measurement of panels bent in a cylindrical shape. The angle at which specular gloss was measured by Mr. Pfund's instrument could be readily adjusted. He examined a number of paint panels submitted by laboratories. Each of the laboratories that cooperated prepared one panel it considered to have high gloss, another considered to have eggshell gloss, and a third considered matte or flat. Mr. Pfund measured these panels for specular gloss at a number of angles and found that gloss readings at 60 deg. were best for separating the three groups of panels into distinct classes according to visual ratings by the laboratories.

In the following two years, essentially the same experiments were repeated by Hunter and Judd[4] who confirmed Pfund's finding that measurements of specular reflection at 60 deg. gave the best separation of panels. Hunter and Judd also varied field angles and came to the conclusion that a practical method, suitable for classifying paint finishes according to specular gloss, would be a 60-deg. measurement in which the source and receptor field angles totaled about 5 by 12 deg. The draft of a suggested A.S.T.M. test was included in the Hunter and Judd report.

Experience with Method D 523

A.S.T.M. Tentative Method for Specular Gloss of Paint Finishes (D 523–39 T)[5] was essentially the method given in Hunter and Judd's report. By 1941 there had been some experience with the new gloss test. It was recognized then that the receptor field angle was an important beam-spread dimension. Accordingly the 1939 method was altered to call for measurements of specular gloss at 60 deg. with a receptor field angle 4.4 by 11.7 deg. These particular dimensions were those used in the goniophotometer employed by Hunter and Judd in 1939.

[3] A. H. Pfund, "The Measurement of Gloss," *Journal*, Optical Soc. Am., Vol. 20, p. 23 (1930).
[4] Richard S. Hunter and Deane B. Judd, "Development of a Method of Classifying Paints According to Gloss," ASTM Bulletin, No. 97, March, 1939, p. 11.
[5] 1939 Book of A.S.T.M. Standards, Part II, p. 1155.

In 1940, Wetlaufer and Scott[6] described a refined method for the specular-gloss measurement of paint finishes. They showed that goniophotometric curves give more data about physical factors responsible for glossiness than do mere one-shot determinations of specular gloss. For one-shot determinations however, they showed that better gloss separation of paint materials is obtained when different geometric conditions of measurement are used in the different gloss ranges. Thus, a reflecting angle of 45 deg. and very small field angles gave good separation of high-gloss finishes. With less glossy finishes, however, angles of 60 and 70 deg. were recommended. Narrow field angles, which necessitated the use of plate glass panels to obtain flatness, were recommended.

In 1941, the method of specular gloss measurement proposed by Wetlaufer and Scott was added to Method D 523.[7] To distinguish it from the method of Hunter and Judd, it was designated Procedure B, and the old 60-deg. method was designated Procedure A. In Method D 523–41 T, it was indicated that Procedure A was suitable for classifying paint finishes according to gloss, but that Procedure B was superior for the gloss measurement of finishes, particularly when these finishes were in the high- and low-gloss ranges.

Procedure B was written around measurements made with a goniophotometer that had been designed by Scott. The American Instrument Co. sold a few of these goniophotometers before the war but discontinued their manufacture during the war period.

The Hunter-Judd method was developed from measurements made with the McNicholas goniophotometer,[8] but in Method D 523–39 T plans for a simpler 60-deg. glossmeter were shown. The Henry A. Gardner Laboratory, assisted by Hunter, designed a 60-deg. glossmeter which was like that illustrated in Method D 523–39 T, excepting that a flashlight lamp and reflector were used in lieu of the 100-watt projection lamp and lens. Within the past two or three years the Photovolt Corp. has also developed a 60-deg. glossmeter intended for measurements according to the Hunter-Judd method.

Of the two procedures given in A.S.T.M. Method D 523–41 T, Procedure A has enjoyed by far the wider use. Only a few of the Scott goniophotometers for procedure B were sold. The procedure is complicated by the fact that there are three numerical scales for gloss—one for the high-gloss range, one for the eggshell range, and another for the flat range. The Hunter-Judd method, on the other hand, has been widely used. With war, the attention of paint technologists turned to low-gloss camouflage finishes. Procedure A of Method D 523–41 T was widely used as a method of specifying and measuring gloss of these finishes.

In spite of its widespread use in the paint and finishes industry, experience with the Hunter-Judd method of gloss measurement has not been too satisfactory. It has proved difficult to obtain agreement among gloss results from different laboratories and different, but supposedly identical, glossmeters. Users of glossmeters have learned that it is easy for their instruments to get out of adjustment. With the 60-deg. glossmeter sold by the Gardner Laboratory, positioning of the flashlight lamp with respect to the reflector is critical. When a lamp burns out, or when the relative positions of lamp and reflector change for any reason, readjustment of a Gardner 60-deg. glossmeter is frequently difficult. If the instrument is not properly focused, its results may be seriously in error.

Within the past two or three years, measurements of specular gloss following the Hunter-Judd procedure have improved in reliability. The users of glossmeters are now generally familiar with the importance of proper optical adjustment of their instruments. The National Bureau of Standards has calibrated and sold sets of low-gloss standards

[6] L. A. Wetlaufer and W. E. Scott, "The Measurement of Gloss," *Industrial and Engineering Chemistry, Anal. Ed.*, Vol. 12, p. 647 (1940).
[7] 1941 Supplement to Book of A.S.T.M. Standards, Part II, p. 401.
[8] H. J. McNicholas, "Equipment for Measuring the Reflective and Transmissive Properties of Diffusing Media," *Journal of Research*, Nat. Bureau Standards, Vol. 13, August, 1934, p. 211. (*RP* 704).

which have been widely used. There are also calibrated standards of intermediate gloss such as are now sold by the Gardner Laboratory to improve the reliability of gloss measurements. Last year the Gardner Laboratory changed the design of its 60-deg. glossmeter to one in which positions of reflector and lamp may be more easily adjusted. Old Gardner glossmeters can be altered to include the new adjusting devices.

Widespread use of the Judd-Hunter method of gloss measurement has continued in the postwar period. Technologists in the paint and protective coatings field are generally familiar with the numerical scale in which values higher than about 70 refer to surfaces of high gloss, those from about 6 to 30 refer to eggshell finishes, while those below 2 or 3 refer to matte surfaces almost completely lacking in gloss.

In 1944, a third procedure, designated Procedure C, was added to Method D 523. In the foregoing paragraphs, the author has spoken of the "Hunter-Judd procedure for gloss measurement" rather than Procedure A of Method D 523–41 T. Most of the published references to this test procedure identified it as Procedure A, Method D 523–41 T, but in practice, low-gloss measurements were seldom made in exact accord with the published procedure.

As published in 1941, Procedure A contained a requirement that low readings of specular gloss must always be corrected (diminished) by an amount that would compensate for the diffuse reflectance of the specimen under test. This correction amounts to 2.5 times the diffuse reflectance of the test specimen, or about 2 for an 80 per cent white, and 0.5 for a 20 per cent gray.

Neither the Gardner nor the Photovolt 60-deg. glossmeter is provided with means for determining the amount of this correction, and, so far as the author knows, none of the persons supposedly following Procedure A has bothered to make the intended correction. The correction is always small, and in most cases, unimportant. In 1944, therefore, a Procedure C was added to Method D 523 to give published approval to existing practice. Procedure C is identical to Procedure A except that no correction is made for diffuse reflectance.

Recommended Revision of Method D 523

The scale of specular gloss described by Hunter and Judd and now represented by Procedure C of Method D 523–44 T is known throughout the paint industry. Many workers have used it. Some have used it successfully but others have obtained and reported erroneous results. These errors are not to be attributed to inaccuracy of the published method, excepting perhaps to failure of the published method to emphasize and explain in detail the importance of proper optical adjustments. The errors are to be attributed to the difficulty of adjusting instruments and to the failure of workers to appreciate the importance of proper adjustment.

Instruments have been and are now being improved. Workers now appreciate the need for careful adjusting of instruments and frequent checking with gloss standards similar to the samples being measured. There seems ample justification for retaining this now familiar gloss scale. It has proved useful both in classifying paint finishes for gloss—which it was originally designed to do—and in giving numerical ratings that differentiate the gloss finishes having otherwise identical appearance, provided these finishes are in the intermediate, eggshell, or low-gloss ranges.

On the other hand, it would seem advantageous to separate Procedure B with its three numerical scales from Method D 523. This latter procedure has enjoyed relatively little use and seems unnecessarily to complicate the published gloss test. It is the author's feeling that Method D 523 should be limited in scope to essentially a simple method for the gloss classification of paint finishes.

The Aminco-Scott goniophotometer, around which Procedure B was written, is a goniophotometer that will measure directional reflectance under many different sets of geometric conditions. Among these are those for the single gloss scale recommended below; thus the Aminco-Scott goniophotometer is an acceptable glossmeter according to the following recommended revision of Method D 523.

The proposed new method has been written as a single test procedure. In the matter of correction for diffuse reflectance, which now differentiates Procedures A and C, it is recommended that numerical values of gloss carry the designation "with diffuse correction" whenever such a correction has been applied. With measurements used to classify surfaces according to gloss, diffuse corrections are required at the lower end of the gloss scale. This must be done if visual appraisals of gloss are to be in accord with numerical values.

One further change of note has been made in the recommended method. The receptor window or field stop is circular in shape instead of rectangular. The present window, measuring 11.7 by 4.4 deg., has an odd size of no significance except that it happened to be the size of the window used by Hunter and Judd. A round window has at least two advantages: it can be easily reamed to specified dimensions, which should be accurate to ± 0.005 in. and it is less likely to introduce vignetting (interception of rays that should register). A round window 8 deg. in diameter has a solid angular area only 2 per cent less than that of the present 11.7 by 4.4-deg. window.

A change at this time to a round window 8 deg. in diameter should cause no significant change in the existing numerical scale of gloss. Few measurements made to date have possessed the accuracy which would be required to differentiate measurements made with the present rectangular window from those with the proposed round window. Since provision can probably be made in all existing glossmeters to change round windows for the present rectangular openings, it is felt that this recommended change will work no hardship.

Provision is made in the specification for designating as "equivalent glossmeters" the existing instruments which are not built to specification dimensions but which are

adjusted by trial and error to give essentially the same results as the specified instruments on most samples. It is believed that most of the glossmeters now marketed are merely built to approximate specification dimensions and then adjusted by trial and error to give correct readings on certain calibrated gloss standards. Moreover, it is apparently not possible to adjust these instruments in any other way because of the vignetting and lack of receptor light diffusors in them. With any of these instruments adjusted by trial and error, there will always be the possibility that samples exist on which they do not give accurate gloss values because of geometric patterns of reflection distribution importantly different from those of the gloss standards used in calibrating the instruments.

In the proposed revision of Method D 523, an attempt has been made to clarify a number of points that have previously caused confusion. In spite of these clarifying and other changes, the revision is essentially the Hunter-Judd method for measuring specular gloss and classifying paint finishes first published as an A.S.T.M. Tentative in 1939.

It may be pointed out in closing this discussion that all the problems of gloss testing will not be solved with the completion of Method D 523. A standard method for obtaining goniophotometric curves is badly needed. So is a method for grading shiny, high-gloss surfaces for distinctness-of-image gloss. Methods of test for sheen, contrast gloss, and bloom may also be needed. For the present it can be said that the field of gloss measurement has only been scratched.

PROPOSED REVISED TENTATIVE METHOD OF TEST FOR SPECULAR GLOSS OF PAINT FINISHES (D 523-44 T)

Scope

1. This method of test may be used: (*a*) to classify paint finishes as either glossy, eggshell, flat, or intermediate in gloss, or (*b*) to intercompare paint finishes in the eggshell and lower gloss ranges when these finishes are identical in appearance except for small differences in shininess.

NOTE.—More than one measurement scale is required to evaluate all the important gloss characteristics of paint finishes. Thus, a value of specular gloss does not measure the capacity of a surface to reflect sharp and distinct images, yet capacity to reflect sharp and distinct images is the major factor in gloss evaluations of many paint finishes. Factors sometimes affecting the gloss ratings of paint finishes are defined and discussed in Appendixes I and II, respectively, of the present Tentative Method of Test for Specular Gloss of Paint Finishes (A.S.T.M. Designation: D 523 – 44 T).[1]

Definition

2. *Specular Gloss.*—Specular gloss, for the purpose of this method, is defined as one thousand times the 60-d specular reflectance of a sample measured with apparatus having the illuminating and viewing beams specified in Section 3.

Apparatus

3. (*a*) The apparatus shall consist of a light source giving an incident beam of rays, means for locating the surface of the sample, and a receptor located to receive certain rays reflected by the sample. These three parts shall be combined in a rugged instrument of one of the two types illustrated in Figs. 1 and 2.

(*b*) *Geometric Conditions.*—The axes of the incident and reflected beams shall each be 60 deg. from a perpendicular to the test surface, and the axis of the reflected beam shall be the direction of mirror reflection of the axis of the incident beam. With a mirror in sample position, an image of the source shall be formed at the center of the receptor field stop. The angular diameter of the source measured from the center of the projecting lens shall be no more than 2 deg. The receptor field stop shall be round and shall measure 8 ± 0.05 deg. in diameter.

NOTE 1.—The foregoing angles determine the extents to which rays in the incident and viewing beams may spread from the principal rays (those from center

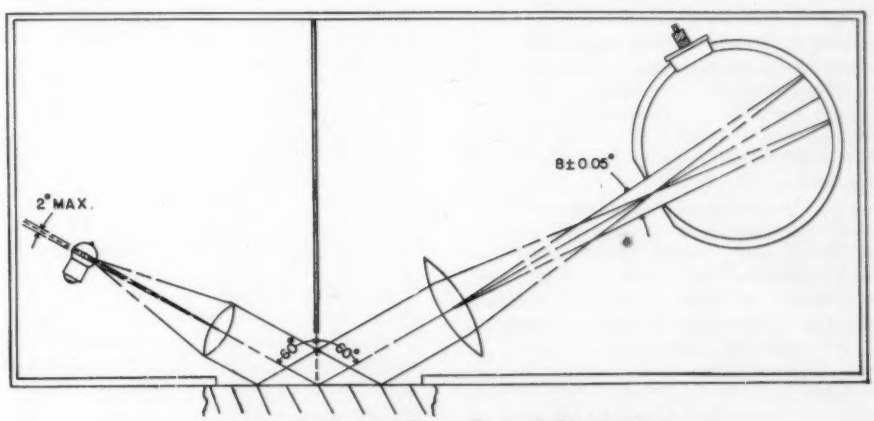


Fig. 1.—Collimated-Beam Type of Glossmeter.

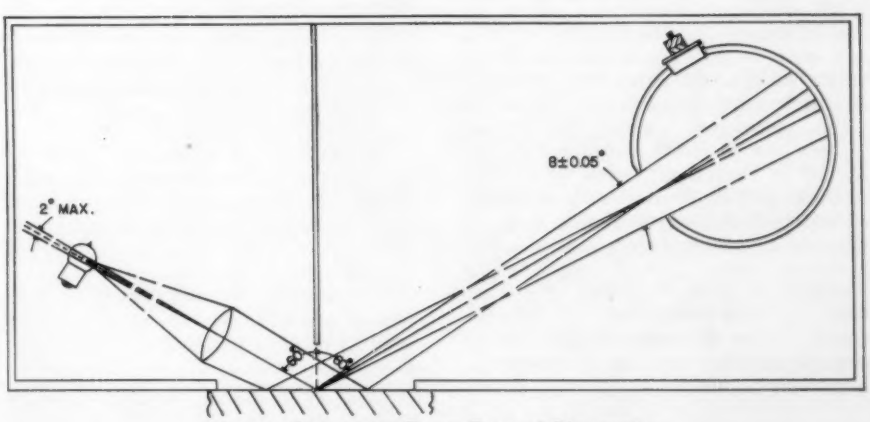


Fig. 2.—Converging-Beam Type of Glossmeter.

[1] 1946 Book of A.S.T.M. Standards, Part II, p. 1587.

of source to center of receptor window) and still register as specularly reflected light. Angular size of the source is measured from the projecting lens; angular size of the receptor window (field stop) is measured from the test surface in a converging-beam type of instrument and from the center of the receptor collimating lens in a collimated-beam type of instrument. If, for example, the projecting lens is 5 cm. from the source, the projected luminous area of the source must not measure more than 5 sin 2 deg., or 0.17 cm. in diameter. Similarly a receptor window 10 cm. from the center of the sample in a converging-beam instrument must measure 10 sin 8 ± 0.05 deg., or 1.392 ± 0.009 cm. (0.548 ± 0.004 in.).

(*c*) *Vignetting.*—There shall be no vignetting or interception by stops or diaphragms of rays supposed to register. That is, all rays shall register at the receptor if they pass the projecting lens or other aperture stop and travel paths to and from the sample that deviate from the paths of the principal rays by no more than half the corresponding field angles in the previous paragraph.

(*d*) *Spectral Conditions.*—The instrument shall give results not significantly different from those that would be given if its source were the standard illuminant *C* recommended by the International Commission on Illumination (I.C.I.) and its receptor had the spectral response of the I.C.I. luminosity function.

NOTE 2.—Since specular reflection by nonmetals is in general spectrally nonselective, it has proved unnecessary in practice to require close duplication of specified spectral conditions. Measurements made with an incandescent lamp as source and a barrier-layer photocell as receptor generally require no spectral correction.

(*e*) *Measurement Mechanism.*—The receptor-measurement mechanism, such as photocell and electric meter, shall give a numerical indication that is proportional to amount of light passing the receptor window within plus or minus 1 per cent.

NOTE 3.—It is generally necessary to employ some diffusor between the receptor window and the photocell to avoid nonuniform weighting of accepted rays resulting from nonuniform response of the sensitive area of the average photocell.

(*f*) *Equivalent Glossmeters.*—If a 60-deg. glossmeter can be adjusted by trial and error to give approximately correct values of specular gloss, but, nevertheless, suffers from vignetting, lack of diffusing mechanism, or other defect so that it does not meet the requirements prescribed in Paragraphs (*a*) to (*c*), it may be designated an "equivalent glossmeter." Although such an instrument may be adjusted by trial and error to give correct numerical values for various working standards of gloss, it cannot be guaranteed that this instrument will give accurate values of specular gloss on all samples tested. Such an instrument is, nevertheless, useful for gloss measurements of types of paint finishes on which it has been proved reliable.

NOTE 4.—Most 60-deg. glossmeters built prior to 1947 must be designated "equivalent glossmeters" because of vignetting, lack of receptor light-diffusing mechanism, and other defects.

Specular Gloss Standards

4. (*a*) The fundamental specular gloss standard shall be the ideal, completely reflecting, perfect mirror which is assigned a value of 1000.

(*b*) Specular gloss working standards may be highly polished, plane, black-glass surfaces for which the reflectance may be calculated as a function of angle of incidence and refractive index by using Fresnel's equation. Polished black glass with a refractive index of 1.52 has a specular gloss of 92.5 on this scale. Surfaces of liquids may also be used.[2]

(*c*) Intermediate and low-gloss standards of ceramic tile, ground opaque glass, emery paper, and other semigloss material having hard and uniform surfaces are suitable working standards of intermediate gloss when calibrated against a polished black glass or liquid on a glossmeter known to be in accurate adjustment. All such intermediate standards should be checked from time to time for constancy of gloss value because contaminations by dirt and filmy deposits frequently cause unsuspected changes in gloss values.

Preparation and Selection of Samples

5. (*a*) This test procedure does not cover the preparation of paint surfaces. There are many factors involved in the preparation of paint finishes that have an important bearing on gloss. Thus, whenever a test for gloss requires the preparation of a test surface from a paint or other material in liquid form, consideration must be given to the matter of sample preparation. It should be noted that washing or rubbing may change the gloss characteristics of a test surface significantly.

(*b*) Only surfaces of good planarity should be tested according to this method. Surface warpage, waviness, or curvature may affect test results importantly. The directions of any brush marks or similar texture effects should be parallel to the plane of the axes of the two beams.

Method of Measurement

6. (*a*) The glossmeter shall be operated according to any instructions of the maker for power supply, warm-up period, dust-free atmosphere, temperature, humidity, and darkness surroundings.

(*b*) Settings on a standard shall be made at the start and completion of every period of glossmeter operation and at intervals during this operation sufficiently frequent to assure that the instrument response is practically constant.

(*c*) At least three portions of the surface of the test specimen shall be measured to give an indication of the degree of surface uniformity and provide an average that is typical of the surface. If any portion of the test surface differs from the average in specular gloss by more than 5 per cent of this average, the fact shall be noted in reporting results.

Diffuse Correction

7. (*a*) All readings taken for the purpose of classifying finishes according to gloss shall be corrected for diffuse reflectance of the surfaces if they are initially less than 15.

(*b*) Readings taken for any other purpose may be corrected for diffuse reflectance at the option of the experimenter.

(*c*) To correct a gloss reading for diffuse reflectance, the daylight 45 deg., 0 deg. luminous directional reflectance of the test surface shall be determined in accordance with the Standard Method of Test for Daylight 45 Degree, 0 Degree Luminous Directional Reflectance of Paint Finishes (A.S.T.M. Designation D 771).[3] This reflectance value in per cent shall be multiplied by 0.025 and subtracted from the glossmeter reading.

NOTE.—In the majority of cases it is possible to estimate this correction without recourse to reflectance measurement. The perfectly reflecting, completely diffusing white (to which a freshly smoked magnesium oxide is a fairly close approximation) would read 2.5 on the above-defined glossmeter. For this reason, 45 deg., 0 deg. luminous directional reflectance relative to MgO (1.00) is multiplied by 2.5 to obtain the diffuse correction. Thus the correction for a 0.80 (80 per cent) white is 2.0; for a 0.40 (40 per cent) yellow it is 1.0, etc. With a little practice, one can learn to estimate 45 deg, 0 deg. luminous directional reflectance to the nearest 20 per cent and thus obtain diffuse corrections to the nearest 0.5.

Report

8. (*a*) Where gloss classifications are desired, the report shall include the gloss rating of the surface as follows:

Surface Having Gloss Values:	Report as Either:	
	Class	or
Above 70.....	A	high gloss
70 to 30, exclusive	B	semi or medium gloss
30 to 6, inclusive..	C	eggshell
6 to 2, exclusive.	D	flat to eggshell
2 and under.....	E	flat

(*b*) Where numerical values are desired, gloss values shall be reported to the nearest unit when over 15, and to the nearest tenth when under 15.

(*c*) If numerical values have been corrected for diffuse reflectance, the fact shall be reported; otherwise, it shall be assumed that diffuse corrections have not been made.

(*d*) The presence of any sample in which portions of the test surface differ in gloss from the average by more than 5 per cent of the average shall be reported.

(*e*) Where preparation of a test surface has been necessary, the method of preparation shall be described or otherwise identified.

[2] D. G. Moore and R. S. Hunter, "Use of Liquid Surfaces as Standards of Specular Gloss," *Journal*, Am. Ceramic Soc., Vol. 24, p. 167 (1941).

[3] 1947 Supplement to Book of A.S.T.M. Standards, Part II, p. 185.

(*f*) If an equivalent glossmeter has been used, it shall be identified by maker's name and model.

(*g*) It is frequently advantageous to identify the working standard or standards of gloss used.

Uncertainty of Results

9. The tolerance given in Section 3 (*b*) permits receptor openings differing by plus or minus 1.3 per cent from the area of the mean opening. This introduces an uncertainty which, at its maximum, has the same percentage magnitude. It is required in Section 3 (*b*) that the measurement mechanism give results accurate to within 1 per cent of any reading. In addition to these two, there are sources of uncertainty in the permitted variations of source size, of lens arrangement, and in reflections from the black interior. Unless working standards similar in gloss and surface appearance to the samples being measured are exchanged and mutually accepted by the interested parties, results of gloss measurement by this method must be considered uncertain by plus or minus 5 per cent of their respective magnitudes.

Report on the Evaluation of Surface Treatment of Steel Prior to Painting

Prepared by Arnold J. Eickhoff[1] on Behalf of Subcommittee XXIX on Painting of Structural Iron and Steel of Committee D-1

THIS is a final report of outdoor exposure tests conducted by Subcommittee XXIX of A.S.T.M. Committee D-1 on Paint, Varnish, Lacquer, and Related Products to determine the effect of cold phosphate–phosphoric acid pretreatments of steel surfaces which were subsequently painted. A progress report[2] was published in 1941.

Pretreatments

The pretreatments investigated were essentially a mixture of water, phosphoric acid, chromates, reduced chromates, wetting agents, and metallic phosphates. The hot type phosphate–phosphoric acid treatments, such as those used extensively on automobile bodies and refrigerators, have proved advantageous for increasing paint adhesion and for retarding the spread of corrosion between the paint film and the steel surface. However, these hot types are not practical for application to structural steel already erected in the field. Hence the question, "How satisfactory are the cold types?"

Paint formulation was not considered in this project. A considerable amount of such work has been reported previously, for example, the Havre de Grace Bridge Tests[3] some forty-one years ago; reports on Atlantic City Steel Plate Tests[4] some thirty-six years ago; and the reports of Subcommittee XIV[5] about twenty-six years ago.

The cold washes used in this investigation, together with a general description and directions for their use, as supplied by their respective manufacturers, are as follows:

Pretreatment X was a mixture of chromic acid, phosphoric acid, a wetting agent, and some zinc dissolved in the phosphoric acid. The temperature of application was 80 F., the drying time was one hour. The steel surface should not be rinsed prior to application of the paint when this pretreatment is used.

Pretreatment Y was a saturated solution of zinc phosphate in an aqueous solution of phosphoric acid. The temperature of the solution when applied was 80 F., and the drying time was four hours. The work was then rinsed with water and dried for one hour prior to application of the paints.

Pretreatment Z was a homogeneous mixture of phosphoric acid, chromic acid phosphate, water-soluble oil solvent, a wetting agent, and water. The temperature of the solution when applied was approximately 130 F. This solution was applied by brush in sufficient quantity merely to wet the surface. The panels were dried two hours and the grayish deposit formed from the chemical pretreatment was allowed to remain.

Test Surfaces and Paints

In this study the panels used were 2 by 3 ft. by $\frac{3}{16}$-in. hot-rolled steel, with a copper content of not more than 0.06 per cent. In choosing such a large panel, it was believed the results of the tests would be more indicative of actual practice.

Three surface conditions were chosen: one was the original hot-rolled panel with mill scale—the grease and dirt removed with volatile petroleum solvent. The second was the mill-scale panel, considerably rusted, then wire brushed before any pretreatment or paint was applied. The third was a mill-scale panel, sandblasted prior to the application of paint or pretreatment.

Two exposure locations were selected—Bethlehem, Pa. (an industrial atmosphere), and Sayville, Long Island, N. Y. (a rural atmosphere). In addition to the control panels which were not given any pretreatment, each of the surfaces was separately treated with three washes of the phosphate type, before the paint was applied.

There were only two paint systems used, designated system A and system B—each system comprising

NOTE.—DISCUSSION OF THIS PAPER IS INVITED, either for publication or for the attention of the author. Address all communications to A.S.T.M. Headquarters, 1916 Race St., Philadelphia 3, Pa.

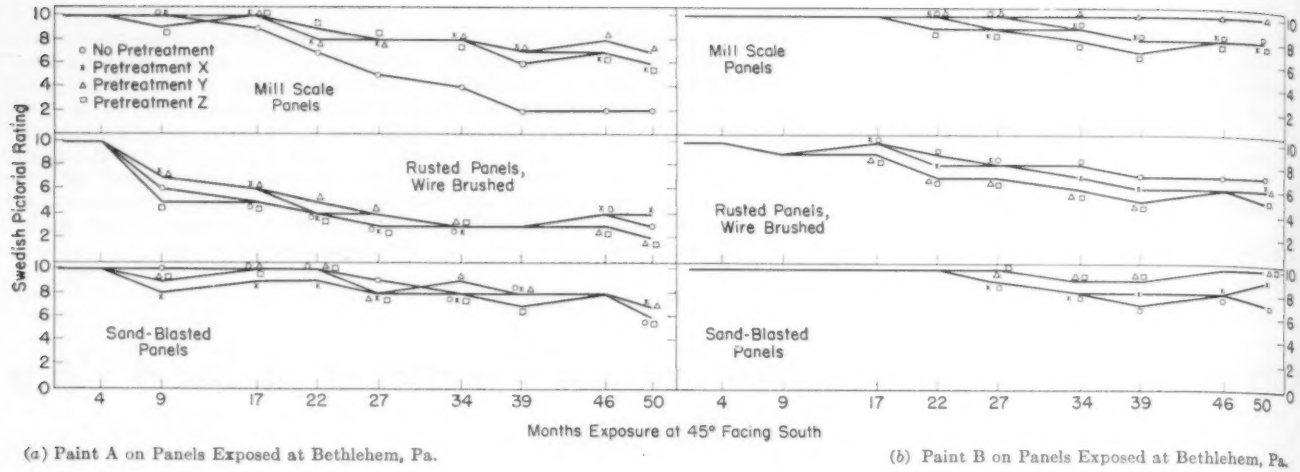
[1] National Lead Co., Research Laboratories, Brooklyn, N. Y.; chairman of Subcommittee XXIX.

[2] *Proceedings*, Am. Soc. Testing Mats., Vol. 41, p. 322 (1941).

[3] Report of Committee E on Preservative Coatings for Iron and Steel, *Proceedings*, Am. Soc. Testing Mats., Vol. VI, p. 47 (1906).

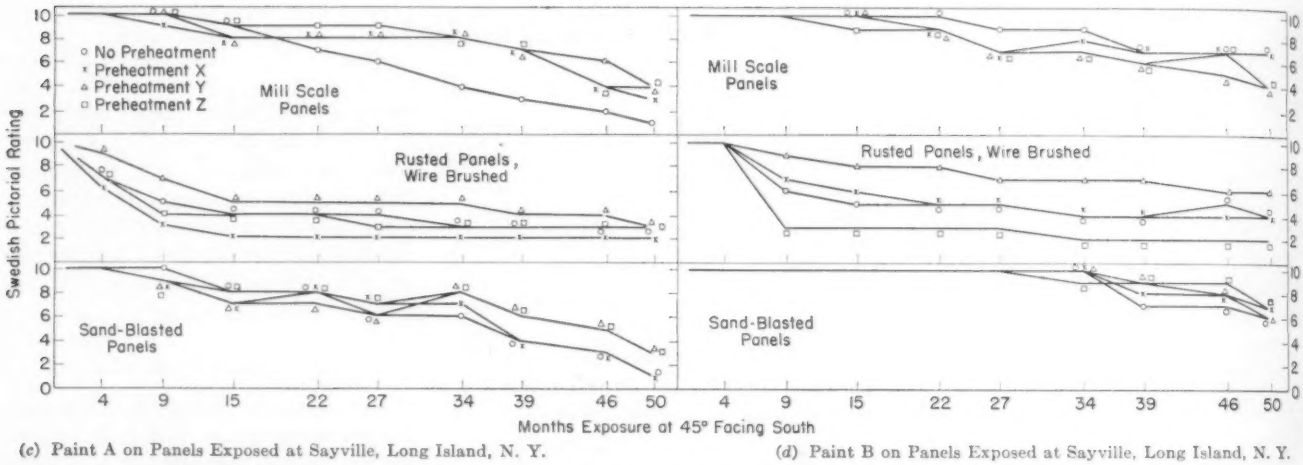
[4] Report of Subcommittee D of Committee D-1 on Preservative Coatings for Structural Materials, *Ibid.*, Vol. XI, p. 192 (1911).

[5] Report of Subcommittee XIV on the Preservation of Iron and Steel Surfaces for Painting of Committee D-1 on Preservative Coatings for Structural Materials, *Ibid.*, Vol. XIX, Part I, p. 374 (1919).



(*a*) Paint A on Panels Exposed at Bethlehem, Pa.

(*b*) Paint B on Panels Exposed at Bethlehem, Pa.



(*c*) Paint A on Panels Exposed at Sayville, Long Island, N. Y.

(*d*) Paint B on Panels Exposed at Sayville, Long Island, N. Y.

Fig. 1.—Swedish Pictorial Ratings of Panels Exposed at Bethlehem, Pa., and Sayville, Long Island, N. Y.

a primer and a topcoat. The paints used in system A were of inferior quality and purposely selected to produce a coating which would not provide prolonged protection. The paints used in system B were considered to be of better quality so that long-time protection would be provided. A total of 24 panels was exposed at each location. The angle of exposure was 45 deg. facing south.

Pictorial Corrosion Standards

Since the committee was chiefly interested in corrosion as an index of protection, a numerical corrosion rating system was desirable. Several sets of Swedish pictorial rusting standards were obtained and, as these were the only pictorial standards then available, they were adopted as a basis for rating corrosion. At a later date the A.S.T.M. Standard Method for Evaluating Degrees of Resistance to Rusting Obtained with Paint on Iron or Steel Surfaces (D 610 – 43)[6] was developed.

In Fig. 1 are shown the progressive ratings for the 50-month test period for each of the paints at each of the locations on panels which had received no pretreatment and on panels given pretreatments *X*, *Y*, and *Z*, respectively. In part (*a*) of this figure is shown the record of paint A on panels exposed at Bethlehem, Pa., and part (*b*), the record of paint B at the same location; part (*c*) is the record of paint A on panels exposed at Sayville, L. I.; and (*d*) the record of paint B at the same point.

Some of the same data are given in Table I which shows for the two paint systems and the several treatments and original surface conditions, the months required to reach ratings of 8 and 6 on the Swedish scale at the two locations. The table also affords a comparison of the Swedish and A.S.T.M. ratings at the conclusion of the tests after 50-month exposure.

The Swedish pictorial rating of corrosion ranges from 0 to 10. A rating of 10 indicates no failure, zero indicates complete failure. These ratings are given for the three different surfaces, and the three pretreatments.

The A.S.T.M. method for evaluating degrees of rusting is also a numerical scale. Number 10 is a surface with practically no blemishes, while the lower numbers indicate progressively worse conditions. However, No. 4 is the worst condition classified under the A.S.T.M. system and the pictorial standards are further divided into two types. Type 1 indicates that the rusting is not accompanied by blistering, while type 2 indicates that the rusting is accompanied by blistering (in the A.S.T.M. system 6-2 indicates a type 2 rusting with a rating of 6).

It will be noted from Table I that

[6] 1946 Book of A.S.T.M. Standards, Part II, p. 1186.

TABLE I.—MONTHS TO REACH SWEDISH RATINGS OF 8 AND 6 AND FINAL SWEDISH AND A.S.T.M. RATINGS OF ALL PANELS

Panel	Paint	Original Surface Condition[a]	Sayville, L. I., N. Y.						Bethlehem, Pa.				
			Pre-treatment	Spreading Rate of Primer	Months to Reach Swedish Rating of:		Final Rating at 50 Months		Spreading Rate of Primer	Months to Reach Swedish Rating of:		Final Rating at 50 Months	
					8	6	Swedish	A.S.T.M.		8	6	Swedish	A.S.T.M.
No. 1	A	M.S.	None	962	19	27	1	> 4-2	800	19	24	2	> 4-1
No. 2	B	M.S.	None	1015	38	50+	7	5-2	775	39	50+	8	8-2
No. 3	A	R. & W.B.	None	934	3	9	3	> 4-2	800	6	9	3	> 4-1
No. 4	B	R. & W.B.	None	831	7	9	4	4-2	650	27	50+	7	8-1
No. 5	A	S.B.	None	883	15	27	1	> 4-1	800	34	50	6	7-1
No. 6	B	S.B.	None	871	37	50	6	4-1	775	34	50+	7	8-1
No. 7	A	M.S.	X	815	15	42	3	> 4-2	800	22	50	6	7-1
No. 8	B	M.S.	X	1015	25	50+	7	5-2	790	39	50+	8	9-2
No. 9	A	R. & W.B.	X	757	2	9	2	> 4-2	650	8	17	4	4-1
No. 10	B	R. & W.B.	X	926	8	15	4	4-2	775	22	39	6	7-1
No. 11	A	S.B.	X	935	12	36	1	> 4-1	695	9	50+	7	7-1
No. 12	B	S.B.	X	795	39	50+	7	8-1	775	34	50+	9	9-1
No. 13	A	M.S.	Y	722	15	46	4	4-2	820	22	50+	7	8-1
No. 14	B	M.S.	Y	746	25	39	4	4-2	775	50+	50+	10	10
No. 15	A	R. & W.B.	Y	739	8	12	3	> 4-2	800	8	17	2	> 4-1
No. 16	B	R. & W.B.	Y	732	15	46	6	5-2	675	19	34	6	6-1
No. 17	A	S.B.	Y	756	12	27	3	4-1	710	27	50+	7	8-1
No. 18	B	S.B.	Y	831	46	50	6	6-1	630	50+	50+	10	10
No. 19	A	M.S.	Z	962	34	42	4	> 4-2	820	27	39	6	7-1
No. 20	B	M.S.	Z	914	25	39	4	4-2	775	34	50+	8	8-2
No. 21	A	R. & W.B.	Z	883	3	6	3	> 4-2	800	6	8	2	> 4-1
No. 22	B	R. & W.B.	Z	892	6	7	2	> 4-2	725	19	34	5	7-1
No. 23	A	S.B.	Z	794	15	40	3	> 4-1	780	27	50	6	7-1
No. 24	B	S.B.	Z	892	48	50+	7	7-1	725	50+	50+	10	10

[a] M.S. indicates Mill Scale, R. & W.B. indicates Rusted and Wire Brushed, S.B. indicates Sandblasted.

in classifying the end-point evaluation of the panels there is, for the most part, reasonably good numerical agreement between the Swedish and the A.S.T.M. systems. Occasionally, one finds a difference, chiefly due to the fact that the A.S.T.M. numbers do not go down so low as the Swedish. On the whole, it is surprising that two pictorial systems developed on the opposite sides of the Atlantic Ocean have such relatively good agreement.

Discussion of Data

Data on the number of months required to reach the Swedish ratings of 8 and 6 are given in Table I. At a rating of 8, repainting is generally considered economically desirable. At a rating of 6, repainting is generally considered to be imperative and extensive surface preparation is required if the paint is to afford reasonable future protection. It will be noticed that at the end of 50 months there are 16 panels which did not reach a corrosion rating of 6. Therefore, the information obtained or the conclusions which can be drawn are somewhat limited.

From the data given in Table I, Table II has been prepared to show the ratio (in per cent) of the number of months required to reach Swedish ratings of 8 and 6, respectively, for pretreated panels *versus* untreated sheets. The committee concluded that small differences in these percentage ratings were not too significant and arbitrarily grouped them before conclusions were drawn.

A percentage between 85 and 115 indicated no advantage or disadvantage for the pretreatment; for one between 85 and 65 per cent the pretreatment was considered disadvantageous; 65 per cent or less the pretreatment was definitely disadvantageous; between 115 to 135 per cent the pretreatment was considered slightly advantageous; at 135 per cent or more the pretreatment was considered definitely advantageous. On the basis of these percentage limits, the following conclusions are noted.

Conclusions

From the data obtained it is readily noted that there is no consistent advantage or disadvantage in the indiscriminate use of the pretreatments on steel exposed to the atmosphere.

It should be noted that if the mill scale is tightly adherent over the entire surface, a condition seldom obtained from a practical standpoint, the paint performance is not adversely affected. This would explain the equally excellent performance of the mill-scale surfaces compared with the sandblasted surfaces.

Wire brushed, rusted panels gave very short paint life under all conditions.

Future Study

Most metal protective paint studies which have been reported in the technical literature have concerned themselves with the preparation and

TABLE II.—RATIO (IN PER CENT) OF MONTHS TO REACH SWEDISH RATINGS OF 8 AND 6 FOR PRETREATED *VERSUS* UNTREATED SHEETS.
(Three types of original surfaces.)

Swedish Rating	Pre-treatment	Mill Scale				Wire Brushed				Sandblasted			
		Sayville		Bethlehem		Sayville		Bethlehem		Sayville		Bethlehem	
		Paint A	Paint B	Paint A	Paint B	Paint A	Paint B	Paint A	Paint B	Paint A	Paint B	Paint A	Paint B
8	X	79	66	116	100	67	114	133	81	80	105	26	100
8	Y	79	66	116	128	267	214	133	70	80	124	79	147+
8	Z	179	66	142	87	100	86	100	70	100	130	79	147+
6	X	156	100±	208	100±	100	167	189	78−	133	100+	100+	100±
6	Y	170	78−	208+	100±	133	511	189	68−	100	100	100+	100±
6	Z	156	78−	163	100±	67	78	89	68−	148	100+	100	100±

painting of new, unweathered steel, or steel cleaned by various mechanical means. Our subcommittee decided that valuable information would be derived from a study of the effect of cleaning, pretreating, and repainting steel surfaces which had received no pretreatment and surfaces which had received mechanical and chemical pretreatments. Consequently, the second phase of this work is concerned with the preparation and painting of the same original painted and weathered panels reported earlier in this report. It is of practical interest to know whether the repainted panels will perform in the same manner as when originally painted. This second phase of the original investigation is now under way and the panels are exposed at the same locations—Sayville, Long Island, N. Y., and Bethlehem, Pa.

APPENDIX

In order that there be no misunderstanding, and to avoid giving the impression that these cold phosphate washes are of questionable value, attention is called to the work done by the U. S. Army Engineers and the Tennessee Valley Authority. Invariably, these cold pretreatments proved of value when used on sandblasted steel surfaces subsequently painted and submerged in fresh water.

Under these conditions of exposure, chemical pretreatment extended the protective life of the applied paint coatings. On the other hand, the use of these same pretreatments applied in a similar manner did not significantly extend the protective life of the paint coatings exposed to atmospheric environments, which finding was developed as the result of the work of Subcommittee XXIX.

Why Shoot A Dead Man?—Or Applied Ordnance Research

THE Ordnance Laboratory at Frankford Arsenal has recently issued an interesting brochure which gives an account of its history and present organization. The official beginning of the laboratory came in 1892 when a Captain John Pitman was assigned to the Arsenal to organize a chemical laboratory to study smokeless powder. Pitman, the brochure recalls, was a tireless worker who performed innumerable experiments on smokeless powder variables, filling in his spare time with ammunition design, and not overlooking the fine opportunity afforded by the city morgue to test the power of experimental bullets against assorted cadavers.

The laboratory grew apace and by 1900 was regarded as the explosives testing center of the United States. World War I put chemistry and metallurgy in top place on the laboratory calendar and it became a production shop as well as a technical division. Among its achievements were its development and standardization of armor piercing bullets, cartridge cases and compositions for the new tracer bullets which were one of the surprises of World War I.

In 1934 it was established as the center of non-ferrous metallurgy for the Ordnance Dept., and the following year a fully equipped ballistics section was installed. Starting in 1940 under Col. L. S. Fletcher and continuing under Col. C. H. Greenall with Sam Tour as civilian director of research, a rapid expansion occurred which trebled its working area and multiplied its staff by twenty. C. C. Fawcett is now the director of the laboratory, and Herschel Smith and E. R. Rechel are asistant directors.

The laboratory, as currently organized, consists of six research branches and six service branches. The Chemical Research Branch, under J. W. Mitchell, is divided into six sections covering engineering, physical, organic, industrial, and inorganic chemistry. The Metallurgical Research Branch, under the joint direction of Harold Markus and A. L. Jamieson, has sections covering copper alloys, design metallurgy, heat treatment, metallography, and mechanical metallurgy.

The Physics and Ballistics Research Branch has grown from a single 50-ft range in an attic in 1934 to one of the most important branches of the Laboratory. Directed by Dr. Smith, its best-known contribution is the basic theory of the recoilless rifle which has been successfully applied in 37-mm., 57-mm., and 105-mm. guns. The series of cal. 0.60 rounds were also developed at the Laboratory. The Ballistics Section now operates eight ranges that can be adapted to the firing of a wide variety of weapons: single shot, semiautomatic, and automatic. Tests are commonly made on small arms ammunition; 20-mm. and 37-mm. cannon; and on bazookas and pilot ejection catapults. The Applied Physics Section of this branch is especially interested in the basic research on physics of metals.

The Mechanical Engineering Research Branch under the direction of S. M. Lawrence has sections on design engineering and development engineering. The Finishes Research Branch, under Max Frager, has sections dealing with organic finishes, protective engineering, and corrosion. Many important activities are covered in the Tropicalization Section of this branch which was established to study the peculiarities of tropical deterioration of certain ordnance items and to find means of preventing it. Much of this work is done in the field, especially at the testing station in the Canal Zone.

The Mathematics Branch is primarily concerned with the use of statistical techniques and their application to design inspection plans and quality control systems. One of its important achievements was the development of quantitative measures of the sensitivity of primers.

The Materials Engineering Branch under L. H. Adams has sections dealing with specifications and materials, shop problems, pyrometric control, and electronic development.

The Materials Testing Branch, under R. D. France, has sections on mechanical testing, a spectrographic section, and sections dealing with the chemical analysis of metals and of nonmetals. Other service branches of the Ordnance Laboratory include Photography, Library, Patents and Administration.

Of considerable interest to A.S.T.M. members is a tabulation in the brochure showing the representation of Ordnance Laboratory personnel on technical committees where representatives on some 14 A.S.T.M. committees are listed.

The Technique of Nailing

Engineering News-Record in the October 2 issue has an interesting item on the homely art of driving nails. This may be of help to those members who pursue the hobby of woodworking within the sanctity of their own homes or have aspirations to build that addition to the garage.

In this article the author, T. H. McKaig, points out that "nails driven in holes $\frac{1}{32}$- to $\frac{1}{16}$- in. smaller than the diameter of the nail will have considerably greater resistance to pull and shear than nails driven without holes. Cement coated nails are considerably superior to uncoated nails. The length of nails for best service should be somewhat more than twice the thickness of the member holding the heads. Slender nails will hold better than thick nails under repeated shocks and constant weaving action, because they bend without losing their grip at the point. The best results in holding power are given by nails with a short pyramidal point. Either blunt or sharp point reduces this holding power. If a cut nail is driven with the taper sides parallel to the fibers of the

wood, the resistance to withdrawal is greater than when driven in the usual manner, but it is more liable to split."

On the same subject—a recent publication of the Housing and Home Finance Agency, entitled "Technique of House Nailing," November, 1947, has come to our attention. This is a 54-page illustrated booklet, prepared by the Forest Products Laboratory, and contains illustrations of correct nailing techniques covering practically everything from double sills and drop-siding to sub-flooring and shingles. Copies of "Technique of House Nailing" are available from the Superintendent of Documents, Government Printing Office, Washington 25, D. C., at 20 cents per copy.

Shades of the Alchemists

Gold—Mercury—Length

If 1948 becomes a year in which we see an unusually large number of comets or strange heavenly bodies, do not be too greatly surprised. They may be caused by the shades of a number of alchemists in their astral abodes burning up in chagrin and frustration as they read in the December, 1947, *Technical News Bulletin* of the National Bureau of Standards that gold is now being turned into mercury. For at Oak Ridge, Tenn., today, gold (Au^{197}) is being transmuted into mercury (Hg^{198}) for the N.B.S.

For twenty years the Bureau has been recommending that the meter be defined in terms of a primary standard of light wave length, that of red radiation from cadmium vapor, rather than the distance between two lines on a platinum-iridium bar at the International Bureau of Weights and Measures in France, the standard of length since 1889. The present standard has several disadvantages: it is unsuitable in certain fields of measurement; the lines being in effect small furrows, (ten to twelve wave lengths wide) do not lend themselves to precise measurement as we look on it today; and the present meter is not readily reproducible.

Some sixty years ago, A. A. Michelson and E. W. Morley outlined a method for making use of a standard of length based on a light wave length. The heavier the atom, the better such a wave length would be as it would tend to be monochromatic and could be excited to radiate at a lower temperature. Searching systematically for the radiation best suited as an ultimate standard, Michelson discovered in 1892 that the green light of natural mercury is complex, and we now know that natural mercury consists of a mixture of seven isotopes with atomic masses of 196, 198, 199, 200, 201, 202, and 204. He discarded the complex mercury line in favor of the red light of cadmium, although for the visual adjustment of interferometers, the green line of mercury would be much more useful as it is 70 times as intense as the red line of cadmium.

Now the green line of mercury, rejected by Michelson fifty-five years ago on account of its complex structure, has finally, by the production of mercury 198, been freed of its seven-isotope curse. So the green line of Hg^{198} with a wave length that can be determined to an accuracy within one part in one hundred million, according to Dr. William F. Meggers of the Bureau's Atomic Physics Division, stands alone as the most nearly ideal standard of length. Neutron bombardment of gold, which has an atomic mass of 197, to produce Hg^{198} is supplying the isotope in adequate quantities.

Shades of the Alchemists!

Calendar of Society Meetings

Inter-Society Color Council—Annual Meeting, March 2, 3, Hotel Pennsylvania, New York, N. Y.

National Electrical Manufacturers Association—Winter Convention, March 14–18, Chicago, Ill.

American Society of Tool Engineers—16th Annual Meeting and Tool Exhibition, March 15–19, Cleveland, Ohio.

American Railway Engineering Association—Annual Meeting, March 16–18, Palmer House, Chicago, Ill.

Institute of Radio Engineers—March 22–25, 1 E. 79th St., New York, N. Y.

American Society of Mechanical Engineers—Spring Meeting, March 1–5, New Orleans, La.

AMERICAN SOCIETY FOR TESTING MATERIALS—Spring Meeting and Committee Week, March 1–5, Hotel Statler, Washington, D. C.

Society of Automotive Engineers—National Passenger Car Meeting, March 3–5, Detroit, Mich.

American Petroleum Institute—Mid-Continent District Spring Meeting, March 24–26, Broadview Hotel, Wichita, Kansas.

American Institute of Electrical Engineers—Great Lakes District Meeting, April 1–3, Des Moines, Iowa.

Southern Machinery and Metals Exposition—April 5–8, Atlanta, Ga.

National Association of Corrosion Engineers—1948 Annual Convention and Conference, April 5–8, Hotel Jefferson, St. Louis, Mo.

American Society of Civil Engineers—Spring Meeting, April 7–9, William Penn Hotel, Pittsburgh, Pa.

American Petroleum Institute—Southwestern District Meeting, April 14–16, Plaza Hotel, San Antonio, Texas.

Society of Lubrication Engineers—Annual Convention, April 19–21, Statler Hotel, Buffalo, N. Y.

National Petroleum Association—April 21–23, Hotel Cleveland, Cleveland, Ohio.

American Ceramic Society—April 25–30, Palmer House, Chicago, Ill.

American Foundrymen's Association—52nd Annual Meeting, May 3–7, Convention Hall, Philadelphia, Pa.

American Petroleum Institute—Pacific Coast District Meeting, May 6–7, Biltmore Hotel, Los Angeles, Calif.

American Institute of Chemical Engineers—Regional Meeting, May 9–12, Hollenden Hotel, Cleveland, Ohio.

American Petroleum Institute—Division of Refining, 13th Mid-Year Meeting, May 10–13, Benjamin Franklin Hotel, Philadelphia, Pa.

National Fire Protection Association—May 10–13, Hotel Statler, Washington, D. C.

International Petroleum Exposition—May 15–22, Exposition Grounds, Tulsa, Okla.

American Iron and Steel Institute—May 26, 27, Waldorf-Astoria, N. Y.

American Society of Mechanical Engineers—1948 Semi-Annual Meeting May 30–June 4, Milwaukee, Wis.

Society of Automotive Engineers—Semi-Annual Summer Meeting, June 6–11, French Lick Springs, French Lick, Ind.

American Society for Engineering Education—56th Annual Meeting, June 14–18, University of Texas, Austin, Tex.

AMERICAN SOCIETY FOR TESTING MATERIALS—Annual Meeting and Exhibit of Testing Apparatus and Equipment, June 21–25, Book-Cadillac Hotel, Detroit, Mich.

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